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Lithostratigraphy of the Middle Ordovician Salona and Coburn Formations in Central Pennsylvania

Richard Rogers Thompson

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Lithostratigraphy of the Middle Ordovician Salona and Coburn Formations in Central Pennsylvania

by Richard Rogers Thompson
Bethlehem Steel Company, Homer Research Laboratories

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LITHOSTRATIGRAPHY
OF THE MIDDLE ORDOVICIAN
SALONA AND COBURN FORMATIONS
IN CENTRAL PENNSYLVANIA

By

Richard Rogers Thompson*

ABSTRACT

A lithostratigraphic study was made of the Middle Ordovician Salona and overlying Coburn Formations of the Trenton Group in central Pennsylvania in order to contribute to knowledge of the correlations and regional relationships of the formations, as well as to hypothesize their possible depositional environments. The study encompassed foot by foot descriptions of about 20 exposures of the studied rock sequence, and comparative laboratory studies of more than 1,000 fresh and weathered surfaces, 250 etched surfaces, 75 thin sections, 400 insoluble residues and about 15 heavy mineral separations.

The Salona and Coburn Formations each have been divided into two members. In ascending order, the Salona includes the New Enterprise Member, composed almost entirely of black, argillaceous calcilutites, and the Roaring Spring Member, characterized by interlayers of laminated and cross-laminated, fine-grained calcarenite. The Coburn includes the Milesburg Member, with interlayers of *Sowerbyella* and *Sowerbyella*-trilobite bioskeletal calcirudites in alternation with other rock types, and the Coleville Member with interlayers of *Dalmanella* and *Dalmanella*-crinoidal bioskeletal calcirudites.

Zones of contemporaneity provided by metabentonite layers and fossil zones, some newly described, furnish a basis for discussion of the time-space relationships of the rock bodies. The Salona Formation is wedge-shaped and thickens toward the southerly and easterly parts of central Pennsylvania as its upper beds replace the lower beds of the Coburn Formation at gradually higher levels. Concurrently, the Coburn thins by interfingering with the overlying Antes shale as well as the underlying Salona Formation. The New Enterprise Member is a blanket-like deposit over most of the region, whereas other members thicken and thin as do the parent formations. Southward in Franklin County, most parts of the Salona and Coburn Formations are replaced by the calcareous shales and argillaceous limestones of the Martinsburg Formation. The lower part of the Salona Formation is represented there by the thin-bedded calcilutites of the Oranda Formation.

The rocks of the Salona and Coburn Formations were classed into six lithotypes, namely, bioskeletal calcirudites, calcarenites, calcilutites, calcareous shales, metabentonites and dolomitic limestones. The three first-mentioned lithotypes respectively were subdivided into nine sublithotypes on the basis of fossil content, presence or absence of sedimentary structures and percentage of argillaceous material.

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In the Roaring Spring Member and in the Coburn Formation, most of the lithotypes tend to occur in rhythmic deposits, commonly less than 10 inches thick, that generally begin at the base of each rhythm with an abrupt contact. This contact is overlain by a relatively coarser-grained limestone which grades upward into finer-grained limestones and these in turn into calcareous shale. The rhythmic deposits possibly were formed in an area of shallow water in which the sediments were churned up periodically by storm waves or turbidity currents.

The three major lithofacies bodies recognized in the Salona and Coburn Formations correspond to the rocks of the New Enterprise Member, the Roaring Spring Member and the Coburn Formation as a whole. These lithofacies respectively appear to have accumulated in progressively shallower areas with corresponding increases in current strength and improvement of conditions favorable for abundant and varied organisms. They acted together as a transgressive sequence during Salona and lower Coburn time, and as a poorly defined regressive sequence during upper Coburn and lower Antes time.

INTRODUCTION

PURPOSE AND SCOPE

The Salona and Coburn Formations of the Middle Ordovician Trenton Group comprise the uppermost part of the 8,000-foot sequence of Cambro-Ordovician carbonate rocks in central Pennsylvania, as illustrated in Figure 1, and reach a maximum thickness of about 600 feet. They crop out extensively in linear belts along the margins of the eroded anticlinal valleys of the Nittany Arch, as well as southeastward in the smaller areas of Kishocoquillas, Black Log, and Path Valleys, as shown in Figure 2.

In view of the success of detailed investigations of other rock units in Pennsylvania by Rones (1955), Palacas (1957), Donaldson (1959), and Hobson (1958), the writer began a similar study of the Salona and Coburn Formations in central Pennsylvania in an attempt to contribute further to knowledge of their correlations and regional relationships. In addition, it was hoped that petrographic examination of the limestones of the formations would provide data that would enable discussion of their possible modes of origin and depositional environments. Previous to this work, the lithologic features of the Salona and Coburn Formations have been reported only generally, without petrographic investigations.

Twenty exposures of the Salona and Coburn Formations, shown in Figure 2, were measured and described on a foot by foot scale in central Pennsylvania. Several of the more complete exposures were selected as key sections for detailed lithologic study. About 1200 samples were collected for laboratory study from the key sections, at a sampling interval generally dictated by visible vertical changes within

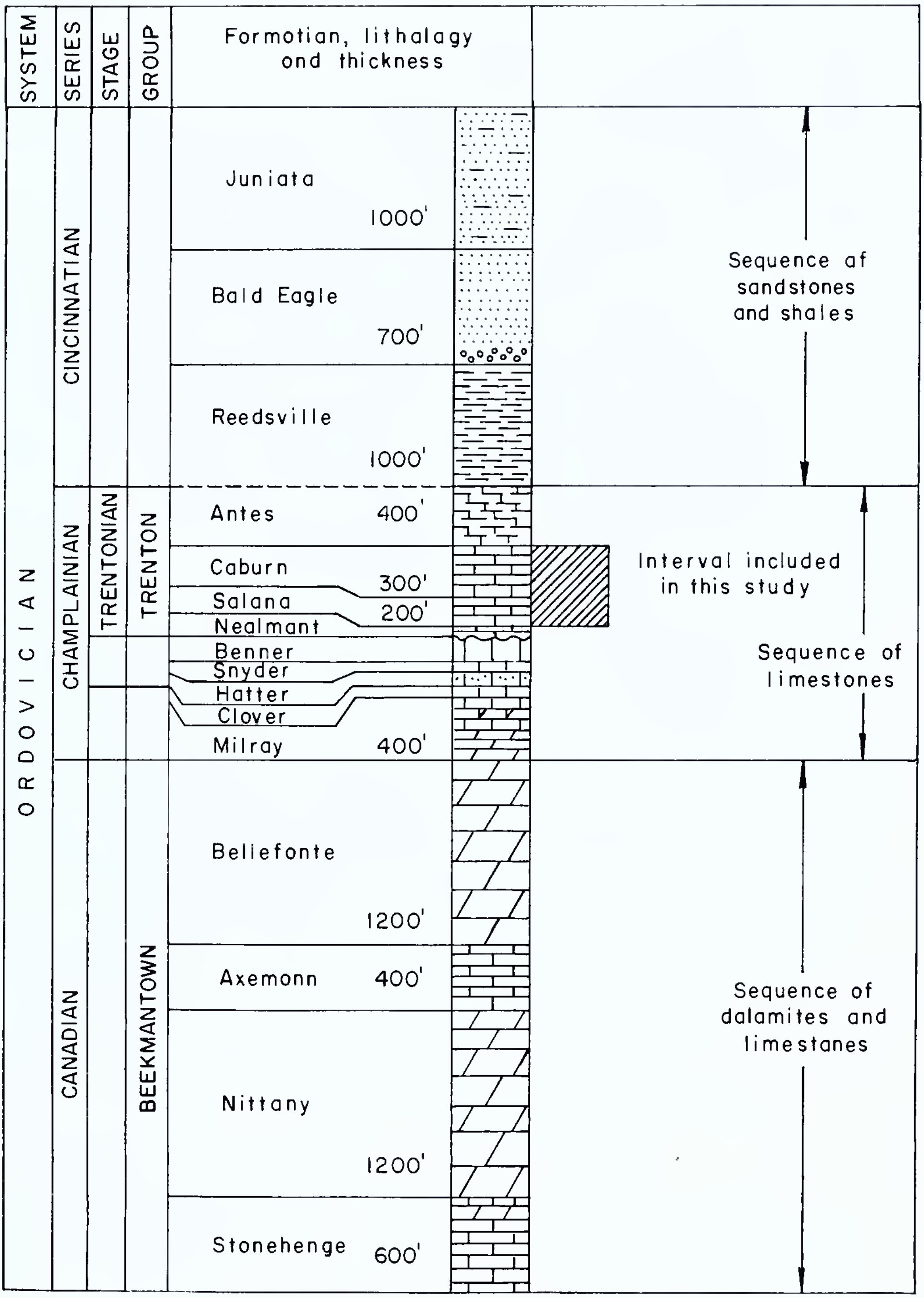

Figure 1. Position of the Salona and Coburn Formations in the Ordovician System of central Pennsylvania

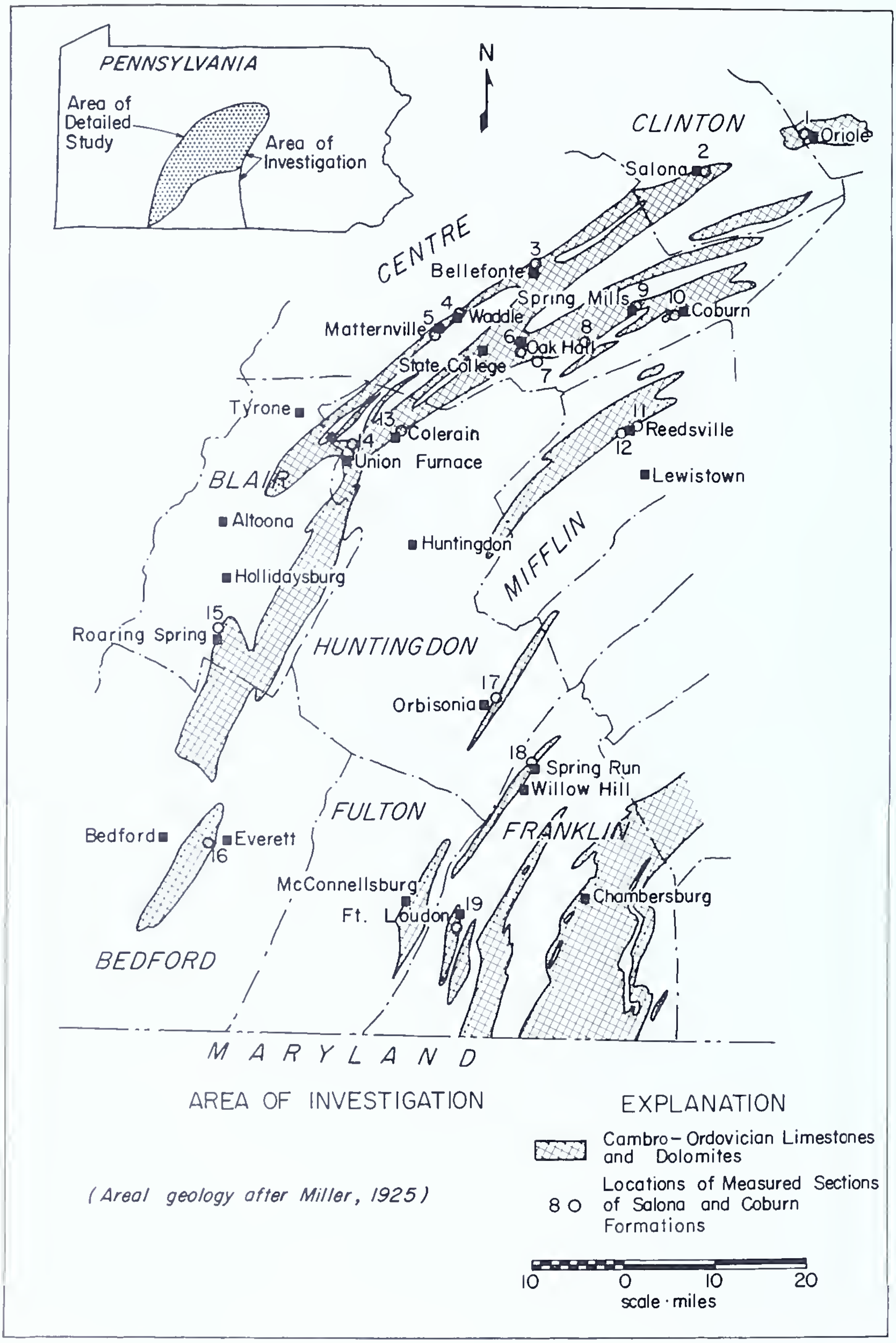

Figure 2. Area of investigation

the rock sequence. The samples were classed into lithotypes and sublithotypes on the basis of composition, texture and sedimentary structure. The lithotype groups were subsampled for preparation of about 250 etched surfaces, 75 thin sections and about 400 insoluble residues. The comparative study of fresh surfaces, weathered surfaces and etched surfaces, as well as of thin sections and insoluble residues enabled the writer to describe the lithotype and sublithotype groups more fully. Once the lithotype and sublithotype groups were established, samples of each were mounted on cards and carried in the field to aid the standardization of rock descriptions.

In the initial stages of the field work, every visible vertical change in the key exposures of the Salona and Coburn Formations was recorded and described. A generalized geological column was drawn for each described section, and the columns were correlated in stratigraphic cross-sectional diagrams as the work progressed. It became obvious at this stage that most of the detailed rock units described initially were not traceable from section to section. Hence, the detailed rock units were grouped into larger units that correspond to the formations and members which are described throughout the following text.

Since this study has concerned itself with only two of the four members of the Trenton Group, it is not an intention of the report to evaluate the validity of the group, and the boundaries and breakdown of the group are accepted as proposed by Kay (1944). The author is using the term "Trenton Group" solely in a rock-stratigraphic sense. A summary of the stratigraphic classifications of the Trenton Group of central Pennsylvania, as developed by Field (1919) and Kay (1944), is presented in Figure 3 along with the refinements of the classification developed in the present work. The development of the classification of the Trenton Group and specifically of the Salona and Coburn Formations is reviewed in the discussion of previous work later in this report.

AREA OF INVESTIGATION

The area of investigation of the present study of the Salona and Coburn Formations, as well as the locations of measured sections, are shown in Figure 2. As indicated in Figure 2 by the density of the measured sections, the principal area of investigation was in Centre County and adjacent counties. In general, exposures of the Trenton Group are good and comparatively closely spaced in Centre County, but become progressively poorer and less numerous toward Franklin County in south central Pennsylvania.

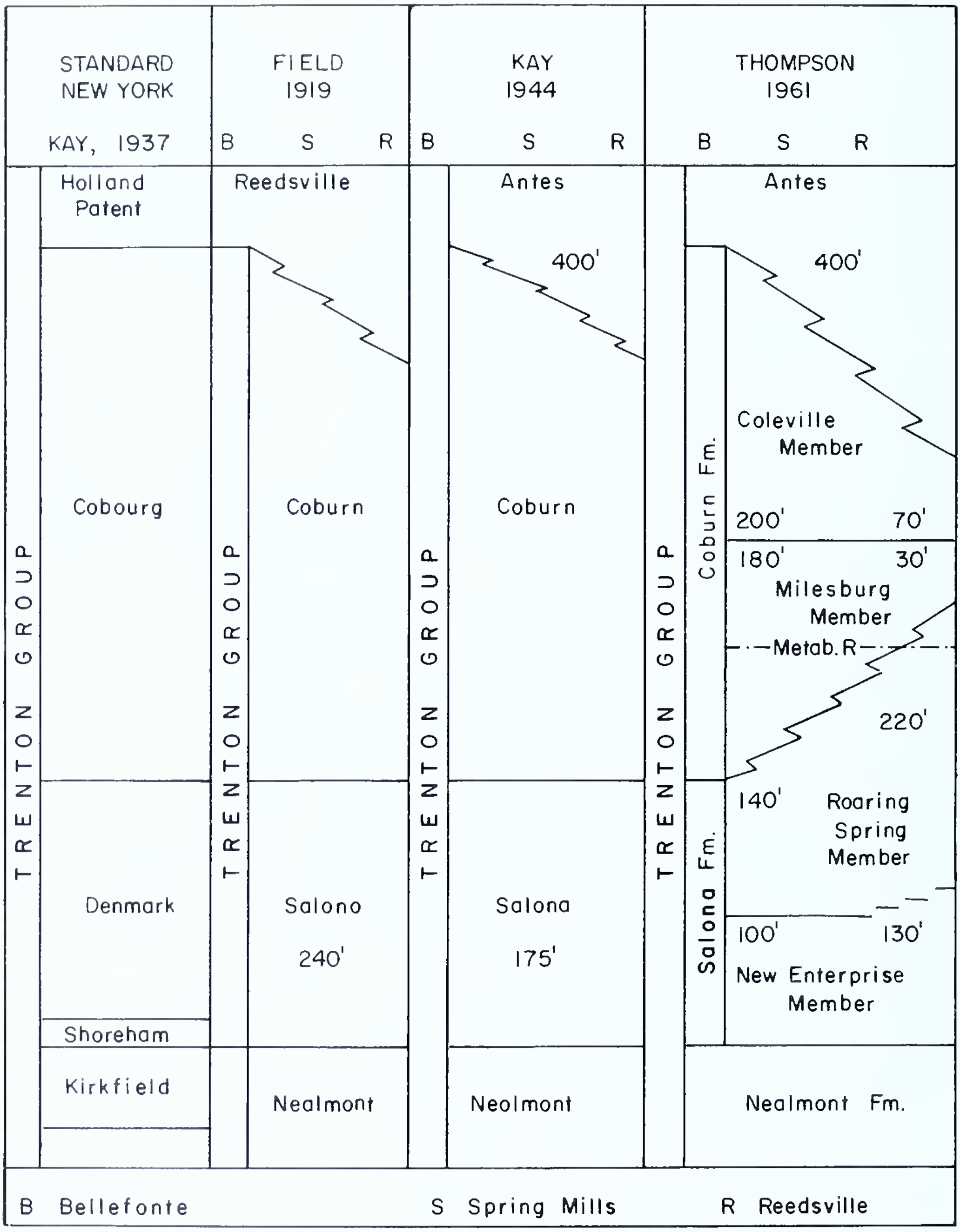

Figure 3. Comparison of classifications of the Trenton Group in central Pennsylvania

ACKNOWLEDGEMENTS

The writer is especially indebted to Dr. Frank M. Swartz, Head of the Department of Geology, who guided the problem and critically read the manuscript. He is also grateful to Dr. Eugene G. Williams for many helpful suggestions and criticisms, and to Dr.

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PREVIOUS WORK

The first reference to the Trenton limestones of central Pennsylvania was made by Rogers (1858), who included them as the lowermost part of the Matinal Series. He classed these black, argillaceous limestones as Trenton, presumably on the basis of their general lithologic similarity to the Trenton rocks of New York, as well as on the presence of *Lingula trentonensis* and a few other fossil forms which he thought were diagnostic. In addition, Rogers (1858) provided illustrations and brief descriptions of some of the common Trenton age fossils.

In 1903, Collie published a comprehensive lithologic and faunal description of the limestones and shales of the Trenton Stage exposed at Bellefonte in Centre County. He divided the 603-foot sequence into eight lithologic units and nine fossil horizons, listing 65 species of fossils and in some instances delimiting their stratigraphic ranges. According to Collie, the basal part of the Trenton Stage is characterized by *Homalonotus trentonensis* and *Cryptolithus tesselatus*.

The Bellefonte section again was measured and described by Ulrich in 1905, as reported by Butts and Moore (1936, pp. 40-41). Ulrich divided the Trenton sequence into nine lithologic units and delimited more closely the stratigraphic ranges of several of the fossil species, especially *Homalonotus trentonensis* Simpson and *Sinuites cancallatus* (Hall).

Field (1919) divided the Trenton limestone at Bellefonte and elsewhere in central Pennsylvania into the Salona and Coburn Formations, in ascending order. His description of these formations is reviewed in more detail where it pertains to the stratigraphic discussions of the present paper.

In 1952, Whitcomb published the summary of paleontologic studies of the Salona and Coburn Formations at Salona in Clinton County and, in addition, furnished the most detailed discussion of the lithology of the formations to this date. Of the many species of fossils that were found in the Salona and Coburn, Whitcomb reported only eight which he thought were especially valuable for regional and interregional correlation. He showed that *Parastrophia hemiplicata*, which marks the base of the Trenton in New York, is found at the base of the Coburn in Pennsylvania, and that *Homalonotus trentonensis* occurs in the Salona Formation, but is absent from the Trenton of New York. On the basis of these observations, Whitcomb concluded that the beds of the Salona Formation are not represented in the Trenton of New York.

In the same study, Whitcomb reported that sparsely fossiliferous, dark argillaceous limestones which comprise the Salona Formation show no signs of having been reworked since their original deposition. On the other hand, he indicated that the abundantly fossiliferous, crystalline limestones, unfossiliferous, dark gray limestones and calcareous black shales which compose the Coburn Formation alternate in such a way as to suggest that they were deposited by the sorting action of some physical process.

Kay (1944) modified the Trenton Group to include, in ascending order, the Nealmont (formerly Black River), Salona, Coburn, and Antes. Classed in this manner, the Trenton Group includes those rocks which lie above a regional unconformity at the base of the Nealmont Formation and below the top of the Antes shale. Kay named the Antes from about 400 feet of dark, brownish weathering shale exposed along Antes Creek in Clinton County. To quote Kay (1944), the Nealmont Limestone is classed as Trenton because, "the assemblage of fossils found in the Nealmont, if collected in New York or Ontario, could only come from the Rockland and Kirkfield Formations". In addition, Kay indicated that the heavy-ledged character of the Oak Hall, the more thin-bedded and argillaceous nature of the Centre Hall and the coarser texture of the Rodman, all Members of The Nealmont Formation, approximate the facies of the Rockland, and lower and upper Kirkfield of Ontario. On the basis of faunal similarity, sequence and frequency of metabentonite layers, he also suggested that the Salona Formation below metabentonite No. 1 should be classed as Shoreham, and above as Denmark. The lowermost occurrence of *Cryptolithus tesselatus* is found at the base of both the Salona and the Shoreham. Kay correlates the Antes shale with the Holland Patent shale of New York, and agrees with previous workers that the Coburn Formation is equivalent in age to the Cobourg. He includes extensive faunal lists, but adds no new species or information about the relative abundances or stratigraphic ranges of species.

Craig (1949) worked out the stratigraphic relationships of Trenton and some of the other Middle Ordovician rocks in south central Pennsylvania and, on the basis of the thinning of the lower part of the Trenton, postulated an arch that apparently trended northeast to southwest through the general area of Path Valley at the time of deposition. He suggested that this arch might be a southerly extension of the Adirondack arch which, according to Kay (1937), existed during Trenton time in New York. In agreement with Kay's interpretations, Craig felt that the arch may have retarded the westward movement of detritals from the southeastern source area during Trenton time.

Schneider (1952) made an extensive paleontologic study of the lower 100 feet of the Coburn Formation at Waddle (section No. 4, Figure 2) and, of the 26 species he listed from these rocks, nine brachiopod species and seven trilobite species are described and illustrated. Two of the brachiopod species and three of the trilobite species are new.

Metabentonite layers comprise less than two percent of the Salona and Coburn Formations, but have received more attention than the remaining percentage of the rock sequence because of their usefulness as key horizons for stratigraphic correlation.

Bonine and Honess (1928) first recognized metabentonite in the Salona of central Pennsylvania and, by emphasizing the physical characteristics of the clays, and particularly the occurrence of euhedral crystals of biotite, apatite, zircon and other heavy minerals in them, established the probable volcanic origin of the layers. In addition, they reported that individual metabentonite layers could not be distinguished petrographically or chemically from one another.

Whitcomb (1932a) recognized five distinct metabentonite layers in the basal part of the Salona Formation and showed that they are traceable to other exposures in central Pennsylvania. He numbered the beds from 1 to 5, in ascending order, and indicated that metabentonites Nos. 1, 2, and 4 are particularly good horizons for stratigraphic correlation. At the type section at Salona, and in most of the exposures in Centre County, Whitcomb reported that metabentonites No. 1 and No. 2 are separated by a maximum of two feet of limestone which is cherty in the uppermost few inches, and that the zone of the trilobite, *Homalonotus trentonensis*, consistently occurs above metabentonite No. 4 and rarely extends above metabentonite No. 5.

Rosenkrans (1933, 1934, 1936) added metabentonite No. 0 at the base of the Salona Formation and extended the occurrence of the six metabentonite layers into parts of south central Pennsylvania. He recognized a 10-inch layer of metabentonite at about 150 feet above metabentonite No. 5 at Reedsville, and suggested that many undiscovered metabentonite layers may exist in other parts of the Trenton Group.

Kay (1935) showed that the metabentonite layers in the Salona Formation appear to increase in thickness toward the south and southeast and postulated that the volcanic ash originated from volcanoes that may have existed in the present location of North Carolina. Kay (1944) later reported the existance of as many as eight metabentonite layers in the Salona Formation at a few localities.

Craig (1949) tentatively extended the correlations of some of the metabentonite layers of the Salona Formation into the Oranda and Martinsburg Formations of south central Pennsylvania.

In a detailed petrographic and X-ray study of selected metabentonite layers and surrounding limestones, Weaver (1953) showed that volcanically derived clay and heavy minerals persist into the limestones as far as seven feet above and below the metabentonite layers, and suggested that a metabentonite merely represents the climax of a volcanic episode which begins gradually and ends gradually.

TERMINOLOGY USED IN ROCK DESCRIPTIONS

The field descriptions of each rock unit reported in this paper include, in the following order, a visual estimation of the composition of the rocks, and statements about grain size, sedimentary structures, weathered and fresh colors, bedding thickness and regularity, abundance and kinds of fossils, and special features. Where more than one lithotype is represented in the rock unit, the dominant lithotype is described first and the subordinate lithotypes are described afterwards, generally in less detail. The percentages of the various lithotypes in the rock units are enclosed in parentheses after the first mention of the lithotype name.

The terminology used in the field and laboratory descriptions of the rocks of the Salona and Coburn Formations is discussed below in the order in which it occurs in the field descriptions.

The rocks of the Salona and Coburn Formations are composed primarily of limestones and shales. As used in this report, a limestone is a crystalline sedimentary rock that effervesces violently in a five percent solution of hydrochloric acid and is assumed to be composed dominantly of calcite. A shale is a very-fine-grained, fissile sedimentary rock that is composed dominantly of argillaceous material, much of which presumably is clay mineral.

The terms limestone and shale may be prefixed by the adjectives calcareous, dolomitic or argillaceous where these subordinate compositional constituents make up recognizable portions of the rocks. In the Salona and Coburn Formations, the dolomitic limestones characteristically weather yellowish brown and contrast with the gray weathering, non-dolomitic limestones. The mineral dolomite was detected in thin sections stained by potassium ferricyanide. The argillaceous limestones generally are finely aphanitic, grayish black and break along argillaceous partings which are on the order of one millimeter thick and spaced less than one inch apart.

Metabentonite, which presumably is altered volcanic ash, commonly is found in the weathered condition and is a yellowish to whitish weathered, massive clay that contains abundant flakes of biotite which are visible on hand specimens.

In the early field and laboratory studies, the limestones of the Salona and Coburn Formations were grouped on the basis of average crystallinity size into the textural classes that are shown in comparison with the Wentworth grade scale in Figure 4. The limits of the textural groups were approximated by the measurement of crystal cleavage faces on fresh rock surfaces under a binocular microscope.

Studies of etched sections and thin sections revealed that most of the limestones of the Salona and Coburn Formations, including some of the coarsely aphanitic limestones are composed, at least in part, of distinct grains which apparently were transported by wave or current action before finally being deposited. These limestones are considered to be clastic and are described by the terms calcirudite, calcarenite and calcilutite which were proposed by Grabau (1924) (See Figure 4). Grabau employs the term clastic for mechanically deposited limestones composed of fragments from pre-existing rocks. Krynine (1954) extended the term to encompass rocks composed of particles or grains that have been rolled around and moved to and fro before coming to rest in the sediment, thereby including rocks composed of mechanically deposited grains of aggradation, such as oolites and certain types of pellets (Illing, 1954), as well as fragments derived from pre-existing rocks. The term clastic as defined by Krynine is used in the present work.

Evidences of the clastic origin of limestones include the recognition of carbonate grains, and the recognition of laminae, cross-laminae, channel and fill structures, and other sedimentary structures which probably reflect movement of grains by current or wave action.

Textural modifiers may prefix a rock term, as illustrated by the term bioskeletal calcirudite, where a particular type of grain comprises a significant portion of the rock.

The non-carbonate particles were classed into size groups according to the Wentworth grade scale.

Sedimentary structures have proved to be useful for (1) classification of some of the sublithotypes, (2) subdivision of the lithologic

Wentworth Grade Scale (mm.)	Crystallinity size based on average size of crystals (mm.)	Clastic grain size based on average size of grains of sedimentation (after Grabau, 1924) (mm.)	Textural modifiers
pebbles 2.0	very coarsely crystalline	calcirudite	Bioskeletal Pellet Crinoidal Argillaceous Arenaceous etc., where these components comprise important percentages of the rock
very coarse sand 1.0	coarsely crystalline	coarse-grained calcarenite	
coarse sand 1/2			
medium sand 1/4	medium crystalline		
fine sand 1/8		fine-grained calcarenite	
very fine sand 1/16	finely crystalline		
silt 1/64	very finely crystalline	calcisiltite	
silt 1/128?	coarsely aphanitic		
silt 1/256	finely aphanitic	calcilutite	
clay			

Figure 4. Textural classifications for rocks of the Salona and Coburn Formations

sequence into members and smaller rock units, (3) interpretation of environmental conditions, and (4), as illustrated by Moore and Scruton (1957), interpretation of paleogeography. The smaller scale sedimentary structures described in the rocks of the Salona and Coburn Formations include laminae, cross-laminae, bands, stringers, graded beds and channel and fill structures. As used in this work, a lamina is less than 5 millimeters thick, whereas a band is greater than 5 millimeters thick. Stringers are discontinuous bands within beds.

The field descriptions of bedding include an estimate of the average bedding thickness, the range in bedding thickness and, in some cases, the distribution of thick and thin beds within the rock unit. Bedding thicknesses are recorded in feet and inches. Bedding irregularities in the form of ripple marks, undulose beds, and lenses also are described.

More than 75 species of fossils have been listed from the Salona and Coburn Formations by Collie (1903), Ulrich (1911), Whitcomb (1932) and Schneider (1952), but the stratigraphic ranges have been established for relatively few of them. In general, only those fossils whose zonal ranges have been established or which occur in great abundance are mentioned in this report.

The symbols used to represent the lithologic and faunal characteristics of the Salona and Coburn Formation in following stratigraphic diagrams are indicated in Figure 5.

INTRODUCTION TO THE LITHOTYPES AND SUBLITHOTYPES OF THE SALONA AND COBURN FORMATIONS

List of Lithotypes and Sublithotypes

On the basis of field studies and the laboratory examination of fresh and weathered surfaces, etched surfaces and thin sections, the six lithotypes and nine sublithotypes listed in Table 1 were recognized in the Salona and Coburn Formations.

The lithotype classification is based on mineral composition and grain size. The sublithotypes of the calcirudites, calcarenites and calcilutites respectively are based on fossil content, the presence or absence of sedimentary structures and the relative abundance of argillaceous bands and partings.

The limestones, including lithotypes No. 1 through No. 3, are listed in Table 1 in order of decreasing grain size. In general, these lithotypes become progressively darker and more argillaceous with the decrease in grain size. Analyses of about 400 samples indicate that the percentage of insoluble residue increases from less than 10 percent

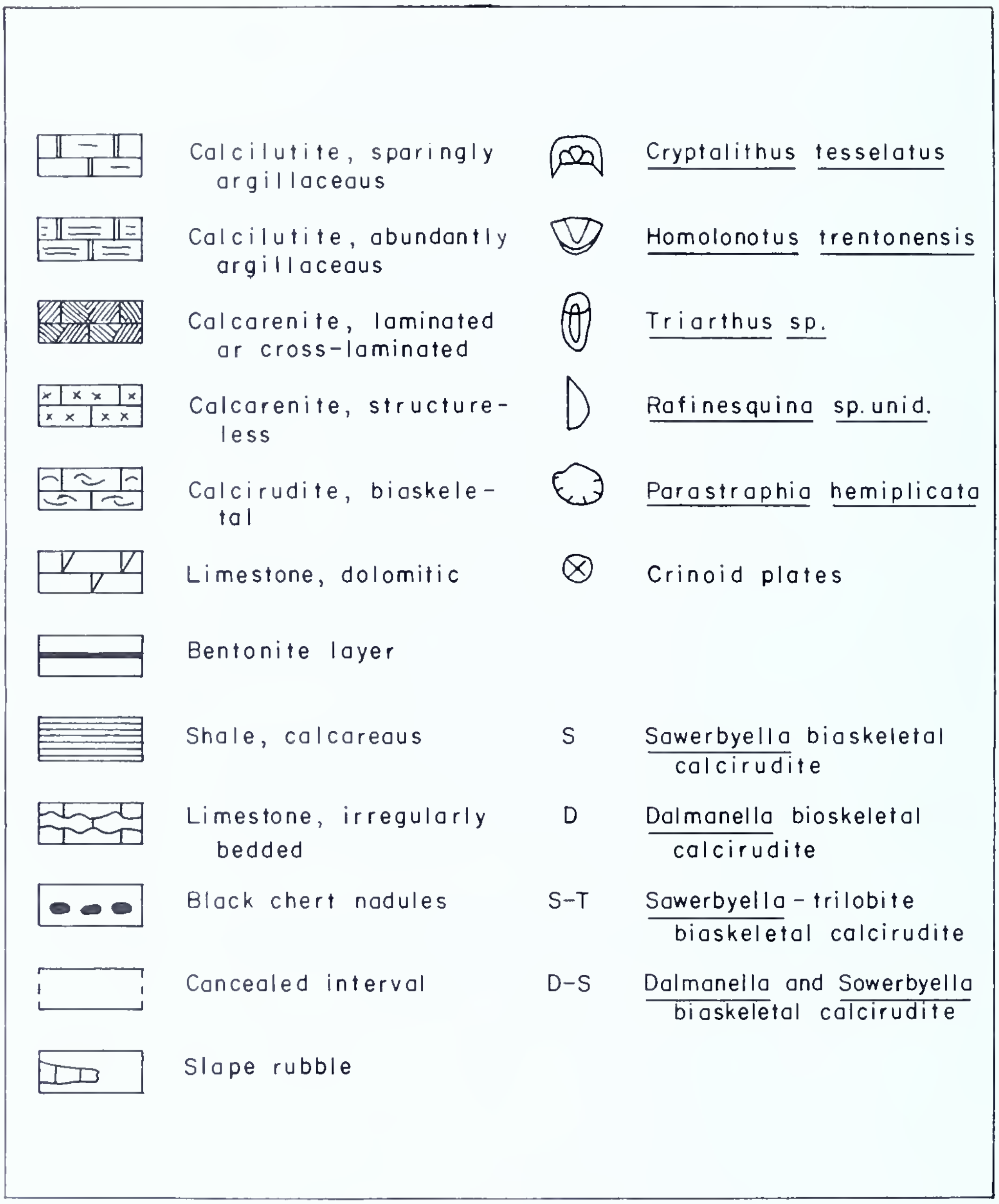
Calcilutite, sparingly argillaceous
Calcilutite, abundantly argillaceous
Calcarenite, laminated or cross-laminated
Calcarenite, structureless
Calcirudite, bioskeletal
Limestone, dolomitic
Bentonite layer
Shale, calcareous
Limestone, irregularly bedded
Black chert nodules
Concealed interval
Slope rubble
Cryptolithus tesselatus
Homolonotus trentonensis
Triarthus sp.
Rafinesquina sp. unid.
Parastrophia hemiplicata
Crinoid plates
S
Sowerbyella bioskeletal calcirudite
D
Dalmanella bioskeletal calcirudite
S-T
Sowerbyella-trilobite bioskeletal calcirudite
D-S
Dalmanella and Sowerbyella bioskeletal calcirudite

Figure 5. Symbols used in stratigraphic diagrams

in the calcirudites to about 15 to 30 percent in the calcilutites. About 10 percent of the tested samples of calcarenite and calcilutite contain as much as 40 percent of insoluble residue which is composed partly of microcryptocrystalline quartz. These observations show that the lithotype groups are somewhat gradational in their physical and chemical characteristics.

The calcilutites of the Salona and Coburn Formations are characterized especially by their nearly black color. In comparison to the color chart distributed by the Geological Society of America, these rocks range from dark gray (N3) to grayish black (N2). Limestones as dark as these do not occur in abundance in any other part of the Cambro-Ordovician limestone and dolomite sequence in central Pennsylvania.

General Characteristics of the Lithotypes and Sublithotypes

The distinguishing megascopic characteristics and the more important microscopic characteristics of the lithotypes and sublithotypes of the Salona and Coburn Formations are reviewed in the following discussion. Photographs of acid etched sections of the characteristic rock types are shown in Plates 1, 2, 4 and 5, and megascopic descriptions of the lithotypes and sublithotypes are summarized in Table 1. The symbols used for the rock types in the following stratigraphic diagrams are indicated in Figure 5.

Bioskeletal Calcirudite (Plates 1 to 3, all Figures)

The bioskeletal calcirudites are limestones composed of at least 20 percent and as much as 60 percent of fossil fragments and parts that commonly are cemented by sparry calcite, although a matrix of lime mud and intermixed argillaceous material usually is present in various amounts. Because of the abundance of fossils, the bioskeletal calcirudites contrast with other limestone lithotypes of the Salona and Coburn Formations that, in general, contain less than five percent of fossils.

The fossil groups most abundantly represented in the bioskeletal calcirudites are brachiopods, trilobites and crinoids. About 90 percent of the brachiopod valves and fragments are remains of the genera *Dalmanella* and *Sowerbyella*, which are illustrated in Plate 3. On the basis of the dominance of specimens of these genera, as well as of specimens of trilobites and crinoids, the bioskeletal calcirudites can be subdivided into the five sublithotypes listed in Table 1. Additional sublithotypes characterized by shells and fragments of bryozoans, gastropods, cephalopods and ostracodes occur in some parts of the Coburn Formation, but are unimportant both volumetrically and stratigraphically.

Calcarenite (Plate 4, all Figures)

In hand specimens, the calcarenities of the Salona and Coburn Formations are very finely crystalline, medium dark gray, and sparsely fossiliferous, and thus contrast with the abundantly fossiliferous, bioskeletal calcirudites, as well as with the black, aphanitic calcilutites.

The calcarenites are divisible on the basis of the presence or absence of sedimentary structures into two sublithotypes, namely, laminated or cross-laminated calcarenites and structureless calcarenites. The laminae and cross-laminae are alternations of more argillaceous layers and more calcitic layers. The argillaceous laminae are grayish black and aphanitic, whereas the calcitic laminae are medium dark gray, very finely crystalline and generally contain various percentages of quartz silt. As estimated from examinations of freshly broken surfaces, weathered surfaces and etched surfaces, about 75 percent of the calcarenites are laminated or cross-laminated, and about 25 percent are structureless.

In thin section, the calcarenites are largely composed of grains of carbonate sand cemented by sparry calcite. The grains mostly are very-well-rounded, ovate to elongate, dark-colored, dense pellets which range from about 1/16 to ⅛ millimeter in maximum dimension. The pellets comprise more than 75 percent of the grains in most of the calcarenites and as much as 50 percent of the total rock. Subordinate grains include fossil parts and fragments, worn and partly replaced crystals of quartz and feldspar, and, more rarely, somewhat large, angular to subrounded fragments of argillaceous lime mud. In general, most of the grains are not visible in field examination on either fresh or weathered surfaces, even with use of a hand lens.

The sparry calcite cement which fills most of the interstices in the calcarenites seldom exceeds 50 percent of the rock as seen in thin sections, yet gives the entire freshly broken surface a very finely crystalline appearance. Lime mud fills a smaller percentage of the interstices in the calcarenites.

Calcilutite (Plate 5, all Figures)

The calcilutites of the Salona and Coburn Formations characteristically are aphanitic, nearly black in color and structureless. In thin section, more than 75 percent of the particles in these rocks cannot be resolved clearly and are assumed to be of fine silt or clay size. Scattered crystals and patches of sparry calcite, and calcitic fossil parts and fragments provide the minor crystalline fraction seen in hand specimens.

The calcilutites are divisible on the basis of relative abundance of argillaceous material into two sublithotypes, namely, argillaceous calcilutites and abundantly argillaceous calcilutites. On the basis of analyses of about 75 samples, most of the argillaceous calcilutites contain about 15 to 20 percent clayey insoluble residue, whereas most of the abundantly argillaceous calcilutites contain about 20 to 30 percent. The argillaceous calcilutites commonly are coarsely aphanitic, dark gray and tend to break across bedding with a subconchoidal fracture. The abundantly argillaceous calcilutites generally are finely aphanitic, grayish black and tend to break along shaly partings,

Table 1. *Megascopic characteristics of the lithotypes and sublithotypes of the Salona and Coburn Formations.*

Number of lithotype or sublithotype	Description of lithotype or sublithotype
1.	*Calcirudite, bioskeletal* with greater than 20 percent of fossil shell material, medium crystalline to very coarsely crystalline, medium dark gray (N3.5 to N4.5), weathering medium light gray (N6), in beds, lenses or stringers commonly 2 to 4 inches thick. Weathered surfaces rough due to chertified fossil parts or to non-carbonate grains standing in relief. Most common fossils include brachiopods, crinoids and trilobites; bryozoans, gastropods, ostracodes and cephalopods are less common.
1a.	*Sowerbyella* bioskeletal calcirudite. Species of the genus *Sowerbyella* comprise more than 75 percent of the fossils in the rock.
1b.	*Sowerbyella*-trilobite bioskeletal calcirudite. Trilobite fragments and parts as well as species of the genus *Sowerbyella* comprise more than 75 percent of the fossils in the rock.
1c.	Crinoidal bioskeletal calcirudite. Crinoid plates comprise more than 75 percent of the fossils in the rock.
1d.	Crinoidal-*Dalmanella* bioskeletal calcirudite. Crinoid plates and species of the genus *Dalmanella* comprise more than 75 percent of the fossils in the rock.
1e.	*Dalmanella* bioskeletal calcirudite. Species of the genus *Dalmanella* comprise more than 75 percent of fossils in rock.
2.	*Calcarenite,* very finely crystalline, mostly laminated or cross-laminated, dark gray (N2.5 to N3.5), weathering to medium light gray (N6) or light olive gray (5Y6/1), in 1-foot very sparsely fossiliferous beds that break with a subconchoidal fracture. Numerous burrow-like structures, up to 5 mm. in diameter, subparallel to bedding.
2a.	*Calcarenite, laminated or cross-laminated.* Laminations are alternations of more argillaceous layers and more calcitic, frequently silty layers. Cross-laminations are less than a few inches in amplitude. Beds 2 to 4 inches thick in Roaring Spring Member of Salona Formation and up to 10 inches thick in Coburn Formation. Includes about 75% of calcarenites.
2b.	*Calcarenite, structureless.* Lacks apparent sedimentary structures. Beds commonly 3 to 8 inches thick.
3.	*Calcilutite,* in part laminated, aphanitic, dark gray (N3) to grayish black (N2), commonly in 4- to 10-inch sparsely fossiliferous beds which weather medium light gray (N6) to medium dark gray (N5). Commonly with a weathered crust up to 4 mm. thick. Burrows up to 5 mm. in diameter common.
3a.	*Calcilutite, argillaceous,* coarsely aphanitic, dark gray (N3), commonly breaking across bedding with a subconchoidal fracture when struck with hammer. Sparsely fossiliferous, weathers medium light gray (N6).
3b.	*Calcilutite, abundantly argillaceous,* finely aphanitic, grayish black (N2) weathering medium dark gray (N5), commonly breaking parallel to bedding along clayey partings less than 1 mm. thick into plates less than 1 inch thick. General appearance of tightly cemented calcareous shale.
4.	*Shale, calcareous,* black, fissile, sparsely fossiliferous to unfossiliferous, in ½-inch to 2-foot beds.
5.	*Metabentonite,* gray to greenish gray shale with abundant crystals and books of biotite mica on surfaces parallel to bedding, weathering to whitish or yellowish plastic clay that contains almost no gritty material. Generally lacks good fissility. Commonly occurs in weathered condition, in ½-inch to 1-foot beds.
6.	*Limestone, dolomitic,* similar in character to lithotype No. 2, but with a characteristic yellowish weathering color and less violent effervescence in hydrochloric acid. Volumetrically unimportant.

about one millimeter thick, into plates which generally are less than one inch thick. The abundantly argillaceous calcilutites correspond to the "dark, dense limestones with a shaly fracture" described by Whitcomb (1932).

Although the calcilutites commonly are found in structureless beds, laminae of more calcitic layers occur in about 10 percent of the samples. Cross-laminae were not observed in these rocks. Where weathered, most of the calcilutites are bordered by a buff-colored residual crust which tends to indicate the impure character of the rock.

In thin sections, recognizable grains, consisting mostly of pellets and fossil parts, comprise less than five percent of the calcilutites and are most abundant in the argillaceous calcilutites.

Calcareous shale

The calcareous shales of the Salona and Coburn Formations are grayish black or black, sparsely fossiliferous or unfossiliferous, and have excellent fissility which contrasts with the massive character of the abundantly argillaceous calcilutites. Some of the calcareous shales layers appear to be more clayey than others and tend to lose their fissility upon weathering. These shales may contain some intermixed bentonitic clay.

Metabentonite

The metabentonites are mostly weathered and appear as yellowish to whitish plastic clays which have poor fissility. Where dry, metabentonite has a soapy feel and contains practically no gritty material. Where fresh, it appears as gray or greenish gray, somewhat fissile shale that contains an abundance of megascopic euhedral biotite flakes and books.

The identification of metabentonite as altered volcanic ash is based primarily on the unique suite of included heavy minerals. Separations in bromoform from as little as 20 grams of metabentonite usually provide numerous euhedral crystals of biotite, zircon and apatite which presumably were phenocrysts in the original ash. Zoned and twinned feldspar crystals are less common.

Dolomitic Limestone

The dolomitic limestones of the Salona and Coburn Formations characteristically have a yellowish brown weathered color as opposed to the gray weathered color of the other limestone lithotypes. In other respects, the dolomitic limestones are similar megascopically to the calcarenites. In a five percent solution of hydrochloric acid, the dolomitic limestones effervesce less violently than other limestones, but differentiation on this basis is subjective and cannot be made consistently where the characteristic weathered color is absent.

As estimated in stained thin sections, the mineral dolomite comprises more than 30 percent of most of the studied samples of dolomitic limestone. The dolomitic limestones constitute less than three percent of the studied rocks and generally are concentrated near to metabentonite layers.

STRATIGRAPHY OF THE SALONA AND COBURN FORMATIONS

ORDER OF DISCUSSION

In view of the fact that the Salona and Coburn Formations in part interfinger with each other and thus are related both spatially and temporally, their characteristics and regional relationships are discussed concurrently in the following pages. This is accomplished first by establishment of the vertical variations of both formations at nearly continuous exposures or "reference" sections, followed by the description of the lateral variations and relationships of the formations.

SALONA FORMATION

Definition

The Salona Formation was named by Field (1919) from exposures at the village of Salona in Clinton County, Pennsylvania. He reported the formation at the type locality to consist of black, argillaceous limestones that are closed at the top by several feet of finely cross-laminated, relatively unfossiliferous limestones. The Salona Formation contrasts with the underlying Rodman Member of the Nealmont Formation, composed of gray, 2- to 3-inch nodular beds of bioskeletal limestones, as well as with the overlying Coburn Formation, consisting of abundantly fossiliferous limestones, crystalline limestones and calcareous shales. As reported by Whitcomb (1932), the Salona Formation is 174 feet thick at the type section and increases to about 240 feet thick at Bellefonte in Centre County.

Whitcomb (1932) and Rosenkrans (1934) recognized six metabentonite layers in the Salona Formation, spaced at Salona at 1, 19½, 21½, 36½, 57½ and 88½ feet above the base of the formation. These metabentonites were numbered in ascending order from metabentonite No. 0 to metabentonite No. 5, and, on the basis of their comparative positions and relations to characteristic rock types and faunal zones, were identified at numerous exposures in central Pennsylvania.

As a result of the present investigation, the Salona Formation has been divided into two members which are recognizable in all exposures of the study area except those in parts of Franklin County in south central Pennsylvania. The lower part of the formation is composed of black, structureless calcilutites and is here termed the New Enterprise Member. The upper part is composed of black calcilutites that characteristically contain interbeds of laminated and cross-laminated, fine-grained calcarenites and is here termed the Roaring Spring Member.

The type sections of the New Enterprise and Roaring Spring Members are located at the New Enterprise Company quarry near the town of Roaring Spring in Blair County (section No. 15, Figure 2), where the Salona Formation is continuously exposed. The greater part of the Roaring Spring Member is concealed at Salona.

The characteristics of the members of the Salona Formation as exposed at Roaring Spring, the type section, are discussed in the following pages.

New Enterprise Member at Roaring Spring

The New Enterprise Member is 90 feet thick at Roaring Spring and is composed of calcilutites that as a whole are characterised by their (1) lack of apparent sedimentary structure, (2) aphanitic texture and (3) nearly black color. The calcilutites commonly occur in 6-inch to 1-foot beds and comprise more than 95 percent of the member. The remaining percentage consists largely of metabentonite and calcareous shale.

The rocks comprising the calcilutites are divisible into two sublithotypes, namely argillaceous calcilutites—elsewhere designated sublithotype No. 3a—and abundantly argillaceous calcilutites—designated sublithotype No. 3b. Rocks of the two sublithotypes form subequal percentages of the rock sequence, and occur in alternating rock units that in general range from 3 feet to 14 feet in thickness. However, a body of abundantly argillaceous calcilutite, 32 feet thick, is found at 47 to 79 feet above the base.

Six metabentonite layers, which appear to correspond to those discussed by Whitcomb (1932) and Rosenkrans (1934) from other exposures in central Pennsylvania, have been recognized in the New Enterprise Member at Roaring Spring. Their thicknesses and stratigraphic positions are listed in Table 2 in comparison with metabentonite occurrences at other localities, and their significance is further discussed under the heading "Zones of Contemporaneity."

In general, the calcilutites of the New Enterprise Member at Roaring Spring are sparsely fossiliferous to unfossiliferous. *Cryptolithus tesselatus* occurs at horizons scattered throughout the member, but is more abundant in the lower 40 feet. The trilobite *Hom-*

Table 2. *Thicknesses of metabentonite layers and intervals between metabentonite layers in the New Enterprise Member at localities in central Pennsylvania.*

Locality	Salona		Belle-fonte		Oak Hall		Spring Mills		Reeds-ville		Union Furnace		Roaring Spring		Ashcom		Willow Hill	
Metabentonite No. and Interval	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.
Metabentonite No. 5	2½				5				4		1		1		7		6	
Interval		31		20½		34		13½		27½		7		39½		24		9
Metabentonite No. 4	11		8		8½		3		10		24		8		6		3	
Interval		28		30½		33½		33		27		27		24½		14½		3
Metabentonite No. 3	3		14		6½		6		10		2½		3½		6		1	
Interval		15		16		21		16½		17		25		9½		2		10
Metabentonite No. 2	6		7		6		6		4		4		6		1		6(B1 & 2)	
Interval		1½		1½		2¼		2		1¾		1¾		½		⅓		
Metabentonite No. 1	2½		5		2		2		6		1		3		4½			
Interval		19		19½		15½		14		24		9		5		10½		7½
Metabentonite No. 0	3		1½		2		1			↓		↓	2			↓	2	
Interval to base		0		0		4½		1						4				11½

alonotus trentonensis is found in some of the beds between metabentonite No. 4 and metabentonite No. 5 at 52½ feet to 86½ feet above the base of the member. Species of *Rafinesquina*, *Dalmanella* and *Isotelus* are sparse in number, and a few linguloid brachiopods and crinoid plates are present. In general, the calcilutites are less fossiliferous at this locality than in sections of Centre County.

The New Enterprise Member at Roaring Spring is in conformable contact with the underlying Rodman Member of the Nealmont Formation as well as with the overlying Roaring Spring Member of the Salona Formation. The contacts are placed at positions of most prominent lithologic change. The lower contact, four feet below metabentonite No. 0, is drawn at the top of the 1- to 3-inch nodular beds which characterize the Rodman Member. At the base of the quarry face, the nodular beds of the Rodman Member are little weathered and occur in 2- to 3-foot beds. Where more weathered at neighboring localities, these strata split into irregular 1- to 3-inch layers. Some of the calcilutite beds in the 4-foot interval beneath metabentonite No. 0 contain as much as 20 percent of crinoid plates and in this respect are transitional between the Rodman Member and the New Enterprise Member.

The contacts and general characteristics of the New Enterprise Member are depicted in Plate 6.

Roaring Spring Member at Roaring Spring

The Roaring Spring Member is 76 feet thick at Roaring Spring and is characterized by interbeds of laminated and cross-laminated, fine-grained calcarenites—sublithotype No. 2a—which comprise about 20 percent of the member. Argillaceous calcilutites—sublithotype No. 3a—are the dominant rock type and comprise about 60 percent of the member, whereas abundantly argillaceous calcilutites—sublithotype No. 3b—are rare. The remaining 20 percent of the Roaring Spring Member is comprised of interlayers of calcareous shale, commonly less than 1 inch thick, which separate most of the limestone beds. A single metabentonite, about 9 inches thick, occurs about 40 feet above the base of the member.

In general, the limestone beds of the Roaring Spring Member are 2 inches to 6 inches thick and contrast with the 6-inch to 1-foot beds of the underlying New Enterprise Member. The contrast in bedding thickness is evident particularly along the top of the quarry cut where the beds are well-weathered. Many of the bedding surfaces in the Roaring Spring Member are undulose with a maximum amplitude of about 2 inches.

The abundantly laminated and cross-laminated, fine-grained calcarenites are not evenly distributed through the Roaring Spring Member at Roaring Spring, but comprise about 50 percent of the lower 10 feet, about 30 percent of the upper 35 feet and considerably smaller percentages of other parts. As seen on weathered surfaces, as well as on etched surfaces and less clearly on fresh surfaces, most of the fine-grained calcarenites are composed of alternating laminae of medium dark gray, silty limestone and of grayish black argillaceous limestone. In the lowermost 10 feet of the member, pyrite cubes are common and occur principally in laminae of medium dark gray silty limestone. Numerous black chert nodules, up to 1½ inches in diameter, are found in the uppermost several feet of the member.

The calcarenites, calcilutites and calcareous shales of the Roaring Spring Member tend to occur in rhythmic alternations which commonly are less than six inches thick. Where calcarenites are present, a rhythm begins at the base with an abrupt contact, overlain by calcarenite which grades upward into calcilutite and this in turn into calcareous shale. More commonly, the calcarenite is absent and the rhythms consist merely of alternating calcilutites and calcareous shales, in which case the contact below the limestone layer is less abrupt.

The rocks of the Roaring Spring Member at Roaring Spring are very sparsely fossiliferous. A few linguloid brachiopods were found in calcareous shales near the base of the member, and several specimens of *Cryptolithus tesselatus*, nautiloid cephalopods, brachiopods and crinoid plates were found in the lower 40 feet of the member below the 9-inch metabentonite.

The lower contact of the Roaring Spring Member is placed at the base of the lowermost bed of laminated, fine-grained calcarenite. The contact is depicted in Plate 6, Figure 2, which also shows the abundance of laminated calcarenite beds which occur in the lower part of the member.

COBURN FORMATION

Definition

The Coburn Formation was named by Field (1919) from exposures at the village of Coburn in Centre County, Pennsylvania. According to Field, the lower and middle beds of the Coburn at the type locality consist of alternations of crystalline, highly fossiliferous limestones and black shaly limestones, whereas the upper beds become increasingly argillaceous as the formation grades into the overlying Reedsville shale. In contrast to the Coburn Formation, the underlying Salona Formation lacks abundantly fossiliferous limestones. The Coburn Formation was reported by Field to be about 400 feet thick at Bellefonte and to thin eastward and southeastward toward Coburn and Reedsville, as the upper beds of the formation apparently are replaced at lower and lower levels by the shales of the Reedsville Formation.

Field (1919) reports that where favorably exposed the Coburn Formation begins with the *Parastrophia hemiplicata* zone, and that *Cryptolithus tesselatus* occurs in the upper beds. Totally, more than 70 species have been listed from the Coburn Formation, especially by Collie (1903), Whitcomb (1932) and Schneider (1951).

As a result of the present investigation, the Coburn Formation is herein divided in ascending order into the Milesburg and Coleville Members on the basis of the fossil content of the highly fossiliferous limestones.

The characteristics of the Coburn Formation are best shown at Bellefonte in Centre County (section No. 3, Figure 2) where most of the Milesburg Member and all of the Coleville Member are exposed continuously. This exposure has been selected as the type section for the members of the Coburn Formation in preference to the Coburn section which presently is mostly concealed.

The term Milesburg was used previously by Schuchert (1916, p. 552) for the "Lower Oriskany" of central Pennsylvania. His definition of the term has not been adopted for common usage and should therefore be abandoned in favor of the present definition.

Milesburg Member at Bellefonte

The Milesburg Member comprises the lower part of the Coburn Formation and is characterized especially by interbeds of *Sowerbyella* bioskeletal calcirudite—sublithotype No. 1a—which tend to occur in the lower part of the member, as well as by *Sowerbyella*-trilobite bioskeletal calcirudites—sublithotype No. 1b—which generally are found in the upper part. The bioskeletal calcirudites occur in alternation with calcarenites, calcilutites and calcareous shales.

At Bellefonte, the bioskeletal calcirudites comprise about 10 to 20 percent of the Milesburg Member and occur in ½- to 6-inch beds, bands and stringers, whereas the calcarenites, mostly laminated or cross-laminated—sublithotype No. 2a—compose about one-half of the member and commonly are found in more persistent beds. Argillaceous calcilutites—sublithotype No. 3a—comprise about one-third of the member and are especially abundant in the uppermost 17 feet, as well as in the 12 feet below metabentonite R. The calcarenites and calcilutites commonly occur in 3- to 8-inch beds in the lower 34 feet of the exposed part of the Milesburg Member at Bellefonte, and in 2- to 5-inch beds in the upper 85 feet. Most of the beds are gently undulose, and a few of them pinch out within 20 or 30 feet along the bedding. Interlayers of calcareous shale, generally less than 2 inches thick, separate most of the limestone beds. They constitute about 10 percent of the lower part of the member, but increase in number and thickness in the uppermost 25 feet where they comprise about 20 to 40 percent of the rock sequence.

Four metabentonites, all less than 1½ inches thick, were recognized in the Milesburg Member at Bellefonte at 9, 22, 45½ and 59 feet above the base of the exposure, and a questionable metabentonite occurs at 93½ feet above the base. Of these, metabentonite R, at 45½ feet above the base, is the only metabentonite that appears to be useful for regional correlation. Metabentonite R is about 1½ inches thick and is overlain by 3½ feet of black, calcareous shale that contains a few specimens of *Rafinesquina* sp. This rock unit of metabentonite and shale contrasts with the relatively uniform sequence of limestone layers above and below. In the Milesburg Member, the *Sowerbyella* bioskeletal calcirudites generally are found below metabentonite R, whereas *Sowerbyella*-trilobite bioskeletal calcirudites are found above it.

The bioskeletal calcirudites, calcarenites, calcilutites and calcareous shales of the Milesburg Member tend to occur in rhythmic alternations less than ten inches thick that basically are similar to those described from the Roaring Spring Member of the Salona Formation. A rhythm commonly begins at the base with an abrupt contact which in some cases is irregular and may have as much as one and one-half inches of relief. The contact generally is overlain by relatively coarse-grained limestone which grades upward into more finely grained limestone and this in turn into black, calcareous shale. Corresponding to this upward decrease in grain size, the limestones become darker in color and more argillaceous. The rhythm may be interrupted at any stage to begin a new rhythm.

In about 25 percent of the rhythms, where all of the rock types are present, the *Sowerbyella* bioskeletal calcirudites at the base grade upward through calcarenites and calcilutites into calcareous shales at the top. More commonly, the *Sowerbyella* bioskeletal calcirudites are absent and the rhythms are composed of calcarenites, calcilutites and calcareous shales, and are identical in most respects to the rhythms characteristic of the underlying Roaring Spring Member.

In the Milesburg Member at Bellefonte, some of the beds of bioskeletal calcirudite lense in and out in distances of 10 to 15 feet along the bedding. Where deposited above undulose beds, the bioskeletal calcirudites are thickest over the troughs and are thin or absent over the crests.

In the Milesburg Member at Bellefonte, only the bioskeletal calcirudites are abundantly fossiliferous. In addition to the abundance of species of *Sowerbyella*, the bioskeletal calcirudites in the lower 60 feet of the exposed part of the member contain numerous specimens of *Rafinesquina* sp. Crinoid plates are fairly numerous in the calcirudites throughout the member, whereas *Prasopora* (?) sp. and other bryozoans, nautiloid cephalopods, gastropods and *Dalmanella* sp. are sparse in number. In contrast to the calcirudites, the calcarenites and calcilutites are practically unfossiliferous but contain some burrow-like structures as well as a few brachiopod specimens.

The part of the Milesburg Member presently exposed at Bellefonte is about 120 feet thick and begins at about 300 feet above the base of the Salona Formation, as measured by the writer. In 1919, Field reported the base of the *Parastrophia hemiplicata* zone, which was then exposed, to be located at 240 feet above the base of the Salona Formation. If the 60-foot interval between the reported base of the Coburn Formation and the base of the present exposure were added to the exposed 120-foot thickness of the Milesburg Member, the member would total about 180 feet thick. However, allowances should be made for differences in the measurements made by Field and by the writer.

Coleville Member at Bellefonte

The Coleville Member is 173 feet thick as measured at Bellefonte and is characterized especially by ½- to 8-inch interlayers of *Dalmanella* bioskeletal calcirudite—sublithotype No. 1e—and *Dalmanella*-crinoidal bioskeletal calcirudite—sublithotype No. 1d—which contrast with the *Sowerbyella* bioskeletal calcirudites of the underlying Milesburg Member.

At Bellefonte, the Coleville Member can be subdivided into three rock units on the basis of the fossil content of the bioskeletal calcirudites. The lower rock unit is 9 feet thick and is characterized by interlayers of crinoidal bioskeletal calcirudite—sublithotype No. 1c—and is marked clearly at the base by a 1½-foot bed of crinoidal bioskeletal calcirudite, also used to mark the base of the Coleville Member. The middle unit, 25 feet thick and extending from 9 to 34 feet above the base of the member, contains subequal percentages of *Sowerbyella* bioskeletal calcirudite—sublithotype No. 1a—and *Dalmanella* bioskeletal calcirudite, and is considered a “mixed zone.” The upper unit is 139½ feet thick and comprises the remaining part of the member. This unit is distinguished by interbeds of *Dalmanella* bioskeletal calcirudite and *Dalmanella*-crinoidal bioskeletal calcirudite, although a few layers of *Sowerbyella* bioskeletal calcirudite are found in the uppermost 22 feet. Bioskeletal calcirudites comprise about 10 percent of the lower rock unit, about 20 percent of the middle rock unit and occur in varying percentages in the upper rock unit as discussed below.

The upper rock unit of the Coleville Member can further be subdivided into smaller rock units on the basis of the distribution of the lithotypes. In the lower 35 feet of this unit, bioskeletal calcirudites and partly laminated and cross-laminated calcarenites are dominant, whereas calcareous shales are subordinate and calcilutites are practically absent. In contrast, about 50 percent of the 82-foot interval in the middle of this unit is composed of calcareous shale in interlayers commonly 2 inches to 10 inches thick, whereas calcilutites comprise 30 percent, calcirudites about 10 percent and calcarenites less than 10 percent. The uppermost 22½ feet of the upper rock unit of the Coleville Member are composed more than 80 percent of bioskeletal calcirudite, with thin partings of calcareous shale and a few thin interlayers of calcarenite.

At Bellefonte, the upper rock unit of the Coleville Member is overlain abruptly by the calcareous shales and abundantly argillaceous calcilutites of the Antes shale. A six-inch layer of *Dalmanella* bioskeletal calcirudite occurs at 22 feet above the base of the Antes shale, and fragments of *Sowerbyella* bioskeletal calcirudite are found in the slope debris up to 35 feet above the base, whereas the lower 22 feet of the formation lack bioskeletal layers. *Triarthus* sp. was observed in the shales at 38 feet to 45 feet above the base of the Antes shale.

The bioskeletal calcirudites, calcarenites, calcilutites and calcareous shales of the Coleville Member occur in rhythmic alternations which basically are similar to those in the Milesburg Member, but the alternations differ in detail from place to place in the vertical sequence. In the lower and upper parts of the upper rock unit of the Coleville Member, calcilutites and calcareous shales are present only in small percentages, and the rhythms consist dominantly of alternations of bioskeletal calcirudite and calcarenite. In the middle part of the upper rock unit, the situation is reversed, and the rhythms are composed mostly of calcilutites and calcareous shales. In other parts of the Coleville Member, the rhythms dominantly are composed of calcarenites, calcilutites and calcareous shales, with subordinate percentages of bioskeletal calcirudite.

The beds in the Coleville Member commonly are 4 to 8 inches thick at Bellefonte, with numerous 1-foot limestone beds in the lower 40 feet and numerous 1-foot shale beds in the upper 100 feet. As in the underlying Milesburg Member, many of the bedding surfaces are gently undulose, and some of the bioskeletal layers pinch out within a distance of 10 to 15 feet along the bedding.

The fossils in the Coleville Member, as in the Milesburg Member, are concentrated almost entirely in the bioskeletal calcirudites. In addition to an abundance of crinoid plates and specimens of *Dalmanella* sp., the bioskeletal calcirudites of the Coleville Member contain moderate numbers of *Prasopora* (?) sp. and other bryozoans, *Rafinesquina* sp. and trilobite parts and fragments, as well as widely separated concentrations of *Sowerbyella* sp., gastropods and ostracodes. *Prasopora* (?) sp. is especially abundant in the upper 50 feet of the member and numerous loose specimens are found in the rock debris. The calcarenites and calcilutites of the Coleville Member are practically unfossiliferous, except for a few burrow-like structures and occasional brachiopod shells.

Cryptolithus tesselatus is moderately abundant in the upper 50 feet of the Coleville Member, and a few specimens were found in the lower beds of the Antes shale. At this locality, *Cryptolithus tesselatus* is rare or absent in beds between the upper part of the Coleville Member and the lower part of the New Enterprise Member where specimens are fairly numerous.

REGIONAL RELATIONSHIPS OF THE SALONA AND COBURN FORMATIONS

Introduction

The regional relationships of the Salona and Coburn Formations in central Pennsylvania are described in the following pages by proceeding from the generalities to the specifics. Hence, the stratigraphic framework is established at the formational level before discussing the more detailed lithologic and faunal variations with respect to the members. To a large extent, the temporal and spatial relationships of the Salona and Coburn Formations, as illustrated in the stratigraphic diagrams of this chapter, depend on the correct identification and correlation of zones of contemporaneity provided by metabentonite layers and fossil zones. For this reason, the zones of contemporaneity are discussed before the facies variations of the rock bodies are considered.

Zones of Contemporaneity

Metabentonites

That metabentonite layers provide zones of contemporaneity is based on the conclusion that these deposits originated from volcanic eruptions and were spread over large areas at the same time. The probable volcanic origin of metabentonite layers from certain localities in western United States was demonstrated by Ross (1928), who additionally defined a metabentonite layer and listed criteria for its recognition. The similarity of metabentonite layers in the lower part of the Salona Formation to those originally described by Ross was shown by Bonine and Honess (1928), as well as by Rosenkrans (1934). The wide-spread geographic extent of some of the metabentonite layers in the Salona Formation was demonstrated by Whitcomb (1932), Rosenkrans (1934) and Kay (1944), and for the region of central Pennsylvania is shown in Figures 10 to 12 in this report.

The metabentonite layers in the Salona and Coburn Formations are indicated in the geologic columns in Figures 10 to 12 by dark horizontal lines and are labelled to the left of the columns by the letter B. Correlation lines connecting metabentonite layers from section to section are dashed. Where the dashes are closely spaced correlations appear to be reliable, and where the dashes are widely spaced, correlations are less satisfactory.

As indicated in Figures 10 to 12, the metabentonite layers most clearly traceable in the Salona and Coburn Formations are metabentonites Nos. 0, 1, 2, 3 and 4, which occur in the New Enterprise Member. These layers initially were identified by Whitcomb (1932) and Rosenkrans (1934), who correlated them throughout central Pennsylvania on the basis of their position with respect to the base of the Salona Formation, the *Homalonotus trentonensis* zone and other metabentonites, as well as by their association with distinctive adjacent rock units.

The thicknesses and spacings of metabentonites Nos. 0 to 5 as measured by the writer at nine localities are recorded in Table 2. As shown in the Table, the metabentonite layers in the New Enterprise Member generally are less than 10 inches thick and do not systematically vary in thickness in any direction in the region. Among other reasons, local variations in thickness may be the result of squeezing as the adjacent beds slipped during the structural deformation of the rock sequence. Calcite layers which in some cases are found at the tops and bottoms of the metabentonite layers usually are strongly slickensided.

One of the most striking features of the metabentonites in the New Enterprise Member is that they parallel each other to a remarkable degree over most of the region, indicating that the rocks of the member were deposited almost everywhere at a fairly uniform rate.

As a result of the present investigation, numerous metabentonite layers, not previously described, have been found in the Roaring Spring Member of the Salona Formation as well as in the Milesburg and Coleville Members of the Coburn Formation, but only one of these layers, metabentonite R, is now recognizable throughout the region.

In some northwesterly sections of the region, near Salona, Bellefonte and Roaring Spring, metabentonite R occurs in the lower beds of the Coburn Formation, but southerly and easterly it is found in the upper beds of the Salona Formation (see Figure 10). In the northwesterly sections, metabentonite R is 1 inch to 2 inches thick and is directly overlain by 2 feet to 3½ feet of calcareous shale. Toward the east and southeast, metabentonite R thickens to a maximum of 10 inches at Reedsville, and concurrently the overlying shale loses its fissility and grades into very abundantly argillaceous calcilutite. The fact that this is the only thick shaly unit in the Salona and Coburn Formations, and that everywhere it is associated with an underlying metabentonite layer seems to warrant its usage as a zone of contemporaneity.

South of Reedsville, as illustrated by the Shade Gap section, a large part of the rock sequence is comprised of abundantly argillaceous calcilutites, and metabentonite R and the associated shaly unit are not clearly recognizable.

In contrast to metabentonite R and the metabentonites in the New Enterprise Member, most of the remaining metabentonites in the Salona and Coburn Formations are discontinuous. A few of them are recognizable at three or four sections, as shown in Figures 10 to 12, solely on the basis of their position with respect to metabentonite R and to fossil zones of contemporaneity.

Fossil Zones

In addition to metabentonite layers, the zones of the trilobite *Homalonotus trentonensis* and of the brachiopod *Parastrophia hemiplicata* appear to provide favorable zones of contemporaneity. Both of these fossil species are distinctive morphologically, occur in relatively large numbers within a short vertical range, have a geographically wide-spread distribution and laterally cross some facies boundaries. *Homalonotus trentonensis* has been pictured and described, and its stratigraphic range has been delimited especially by Collie (1903), Field (1919), Whitcomb (1932) and Kay (1944). These workers and Schneider (1951) have provided similar information about *Parastrophia hemiplicata*.

As shown in Figures 10 to 12, *Homalonotus trentonensis* occurs largely in the New Enterprise Member of the Salona Formation, generally from 10 feet to 40 feet above metabentonite No. 4. As reported by Whitcomb (1932) from the Salona section, *H. trentonensis* tends to be more abundant in this interval in the abundantly argillaceous limestone layers. According to the present study, the species seems to decrease in abundance toward the south, where the entire sequence is more argillaceous, and has not been found in sections south of Willow Hill.

Parastrophia hemiplicata was reported by Field (1919) to occur in all sections in central Pennsylvania at the base of the Coburn Formation, but is shown in Figure 10 to occur at lower and lower levels beneath the base toward the southeast. At Waddle and Salona, as described respectively by Schneider (1951) and Whitcomb (1932), *P. hemiplicata* is concentrated in 30 feet of rock at the base of the Coburn Formation, although isolated specimens were found above this interval. The zone appears to thin southeastward and then disappear. At Reedsville, *P. hemiplicata* is found in the Salona Formation in three 1-inch layers within a 1-foot interval. In sections south of Colerain and Reedsville, no specimens were discovered. As shown in Figure 10 and Figure 11, the *P. hemiplicata* zone generally occurs in the interval at 60 to 90 feet below metabentonite R. Perhaps when zonal ranges of more of the species are better understood, additional zones of contemporaneity will be recognized in the Salona and Coburn Formations.

General Relationships of the Formations

The time-space relationships of the Salona and Coburn Formations in central Pennsylvania are generalized in the panel diagram in Figure 9, and are illustrated more fully in the stratigraphic cross-sections in Figures 10 and 11. The thickness values for the formations at localities in the region are recorded on the map in Figure 6.

In general, the Salona Formation forms a wedge-shaped rock body that thickens progressively southeastward by interfingering at its upper boundary with the overlying Coburn formation, whereas its lower boundary parallels recognizable metabentonite layers, except perhaps at Antes Gap in Clinton County where the Salona is reported by Kay (1944) to lie unconformably on bioskeletal mounds of the Rodman Member of the Nealmont Formation. The thickening of the Salona Formation occurs concurrently with a thinning of the Coburn Formation which diminishes by interfingering with incoming parts of the overlying Antes shale as well as of the underlying Salona Formation.

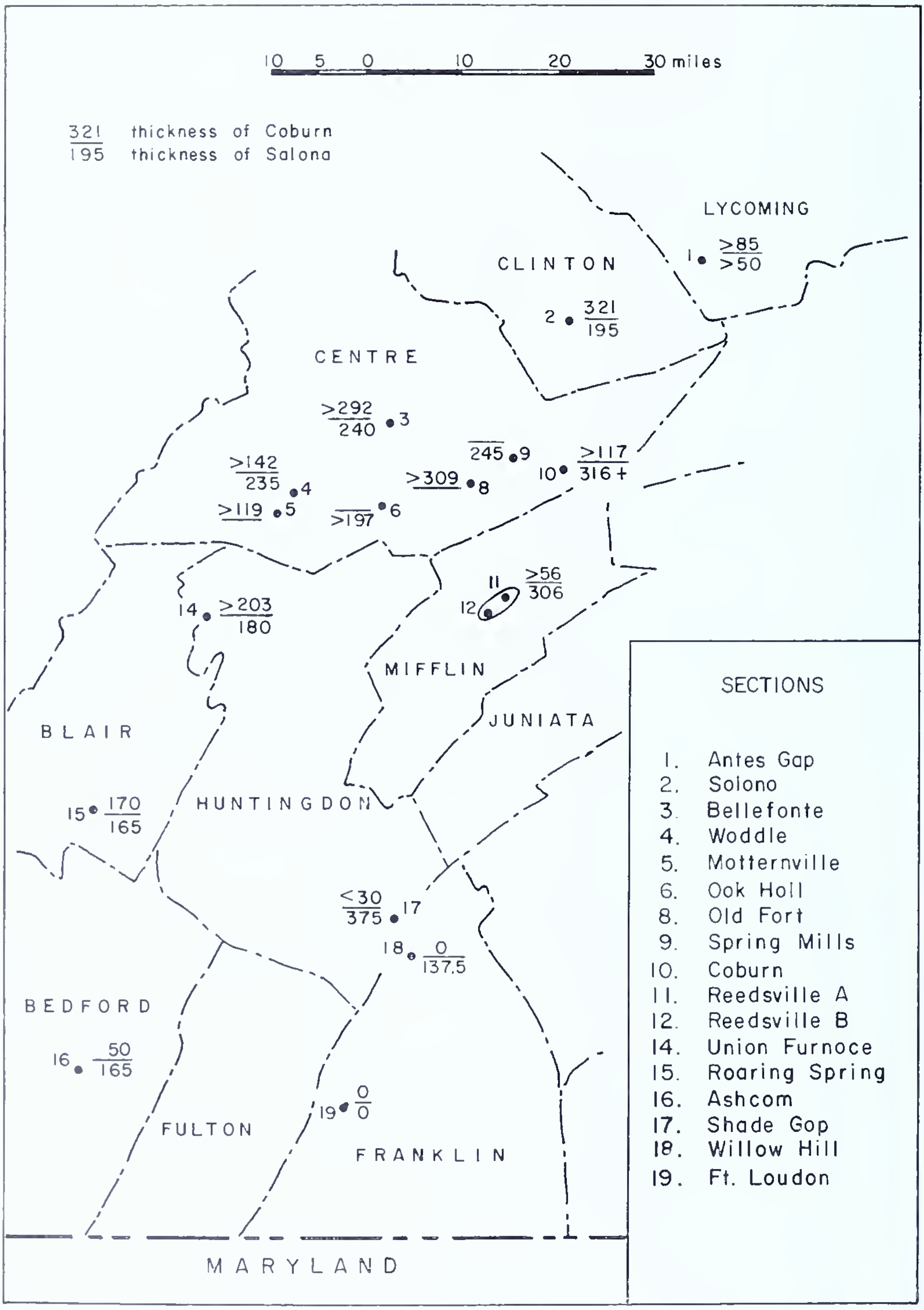

Figure 6. Thicknesses of the Salona and Coburn Formations at localities in central Pennsylvania

Both the Salona and Coburn Formations are replaced southeastward in Franklin County by the calcareous shales of the lower part of the Martinsburg Formation, as described by Craig (1949). The Coburn Formation wedges out south of Shade Gap, whereas the Salona Formation is recognizable as far southeast as Willow Hill. Similar changes possibly take place eastward and southward beyond the study area.

The relationships of formational boundaries to zones of contemporaneity are illustrated in Figures 10 to 12. The lower boundary of the Salona Formation parallels metabentonites Nos. 0 to 4 and the *Homalonotus trentonensis* zone over most of the region, whereas the interfingering boundary between the Salona and Coburn Formations is found southeastward at progressively higher and higher levels with respect to metabentonite R and the *Parastrophia hemiplicata* zone. The upper boundary of the Coburn Formation concurrently occurs at lower and lower levels in relation to the time planes.

The interfingering at the top and bottom of the Coburn Formation apparently takes place on a foot by foot scale, except for an intertongue of the Coburn Formation that is recognizable in the upper part of the Salona Formation at Spring Mills in Centre County, as well as at Colerain in Blair County (see Figures 9 and 10). At both localities, the intertongue occurs at about the same stratigraphic position with respect to the metabentonite R and contains the *Parastrophia hemiplicata* zone. The occurrences of *P. hemiplicata* at Coburn and Reedsville may represent an eastward extension of the intertongue in central Pennsylvania.

Most of the fossils of the Salona and Coburn Formations are discussed with the members in which they dominantly occur. *Cryptolithus tesselatus*, however, appears to have a unique and regionally important distribution. This trilobite, much discussed in the literature, occurs primarily in two distinct zones in the northwesterly sections of central Pennsylvania, one in the lower part of the Salona Formation and the other in the upper part of the Coburn Formation and the lower part of the Antes shale. At Salona and Coburn, the two zones are separated by more than 350 feet of rock in which *C. tesselatus* is very rare or absent. Toward the south and east, where the Coburn Formation thins as it is replaced by the Salona Formation and Antes shale, the interval between the two zones of *C. tesselatus* also thins, so that at Ashcom and Reedsville, the species is found at horizons scattered throughout the Salona and Coburn Formations. This trilobite clearly seems to migrate with a shift in environment.

Facies Variations of the Members

The detailed regional relationships of the Salona and Coburn Formations are discussed in the following pages in relation to the members of the formations. The members are discussed in ascending order.

New Enterprise Member

The New Enterprise Member of the Salona Formation is composed primarily of structureless, nearly black calcilutites which form a remarkably constant 90- to 100-foot blanket-like layer over most of the region, in contrast to the other members which vary considerably in thickness by interfingering with adjacent rock bodies (see Figure 9). The upper and lower boundaries of the New Enterprise Member parallel recognizable metabentonite layers and the *Homalonotus trentonensis* zone except in the southerly part of the region where the upper boundary is found at higher and higher levels above these time marker beds. At Antes Gap, the member is reported by Kay (1944) to lie unconformably on the bioskeletal beds of the Rodman Member of the Nealmont Formation.

As its upper boundary rises toward the south, as illustrated in Figure 10, the New Enterprise Member thickens to 158 feet at Shade Gap where an intertongue of the overlying Roaring Spring Member is recognizable in the upper part of the member. At Willow Hill, south of Shade Gap, the member thins again to 95 feet by an overall decrease in the rate of sedimentation, as evidenced by the fact that the intervals between metabentonites Nos. 0 to 4 thin uniformly. The name New Enterprise Member was not extended to sections south of Willow Hill in Franklin County, where Craig (1949) reports that most of the member is replaced by the "argillaceous limestones" of the lower part of the Martinsburg Formation, and the beds below metabentonite No. 2 are represented by the 2- to 4-inch bedded limestones of the Oranda Formation.

In general, the New Enterprise Member becomes more argillaceous, less fossiliferous and slightly thicker-bedded southward and eastward in central Pennsylvania.

The southward increase in argillaceous material in the New Enterprise Member is illustrated best in sections along the northwestern perimeter of the region where rock units of abundantly argillaceous calcilutite—sublithotype No. 3b—progressively become more numerous and thicker, and occur at higher and higher levels in the member from Bellefonte to Roaring Spring, as represented in Figure 11. At Bellefonte, argillaceous calcilutites—sublithotype No. 3a—comprise more than 90 percent of the member, and abundantly argillaceous calcilutites occur only in a few interbeds less than six inches thick. At Union Furnace, about 35 miles southwest of Bellefonte, the abundantly argillaceous calcilutites occur in 3- to 10-foot rock units, which comprise about one-third of the member and generally are confined to the interval below metabentonite No. 3. At Roaring Spring, the type locality of the member, these rock units increase in number, constitute about one-half of the member and are scattered throughout. The rock units of abundantly argillaceous calcilutite probably are intertongues which individually are not recognizable from section to section.

Rock units of abundantly argillaceous calcilutite, comparable to those at Union Furnace and Roaring Spring, also are found in the New Enterprise Member southeast of Bellefonte, as illustrated in Figure 10. Although much of the New Enterprise Member is concealed in the sections of this area, rock units of abundantly argillaceous calcilutite are recognizable in the *Homalonotus trentonensis* zone above metabentonite No. 4 at Spring Mills, occur throughout the member at Reedsville, and are found up to 55 feet above the *H. trentonensis* zone at Shade Gap.

In general, the beds of the New Enterprise Member appear to become thicker in areas where the rocks are more argillaceous. Beds commonly are 4 to 6 inches thick in the northwestern part of the region where the member is composed mostly of argillaceous calcilutites, and generally are 6 inches to 1 foot thick in the southern and southeastern part of the region where the member is more argillaceous. At Ashcom, in Bedford County, many of the argillaceous beds are 2 feet thick, whereas south of Willow Hill in Franklin County, most of the beds are more shaly and in some cases fissile.

As the sparsely-fossiliferous New Enterprise Member becomes more argillaceous and thicker-bedded, fossils become less abundant both in numbers and kinds. In addition to *Homalonotus trentonensis* and *Cryptolithus tesselatus*, discussed previously, the northwestern exposures of the New Enterprise Member contain species of *Isotelus*, *Refinesquina*, *Dalmanella*, *Sowerbyella*, crinoid plates, nautiloid cephalopods, linguloid brachiopods and trilobite parts and fragments. At Oak Hall, *Leptaena* sp. and *Prasopora* (?) sp. were found in the lower part of the member, and at Salona and Bellefonte, graptolites were seen between metabentonite No. 2 and metabentonite No. 3. In exposures south of Shade Gap in south central Pennsylvania, the variety and relative abundance of fossils diminishes, and only a few specimens of *Cryptolithus tesselatus*, *Homalonotus trentonensis*, crinoid plates and brachiopod parts and fragments are found.

Less striking but perhaps important lithologic changes take place to the north and northwest of the region where the New Enterprise

Member appears to interfinger with the overlying Roaring Spring Member as well as with the underlying Rodman Member. These changes are best seen at Salona where interbeds of Rodman-like bioskeletal calcarenites occur up to 17½ feet above metabentonite No. 0, and several interbeds of laminated and cross-laminated, fine-grained calcarenite which characterize the Roaring Spring Member occur in the upper one-third of the New Enterprise Member. Rodman-like interbeds also occur up to 8 feet above metabentonite No. 0 at Union Furnace. However, the lower contact of the New Enterprise Member at these localities is located below metabentonite No. 0 at the position of pronounced lithologic change. In other sections of the region, interbeds of the Roaring Spring Member are absent from the New Enterprise Member, and Rodman-like interbeds occur only below metabentonite No. 0.

If the lithologic changes described above were projected northward and northwestward beyond the study area, progressively more of the New Enterprise Member might be replaced by interfingering with the Rodman and Roaring Spring Members.

Roaring Spring Member

The Roaring Spring Member of the Salona Formation is characterized by interbeds of laminated and cross-laminated, fine-grained calcarenite which occur in rhythmic alternations with calcilutites and calcareous shales.

In contrast to the blanket-like New Enterprise Member, the Roaring Spring Member varies considerably in thickness in the area of investigation. As shown in Figure 10, this Member maintains a uniform thickness in sections northwest of Old Fort, then thickens toward the south and southeast as its upper beds replace the lower beds of the overlying Milesburg Member at higher and higher levels with respect to metabentonite R and the *Parastrophia hemiplicata* zone. In Figure 11, the Roaring Spring Member is shown to thin from Waddle to Union Furnace. South of Shade Gap, the Roaring Spring Member thins rapidly, and the calcarenites which characterize the member were not found in sections south of Willow Hill. The thickness values of the Roaring Spring Member at localities in the region are shown on the map in Figure 7.

The Roaring Spring Member maintains a rather uniform lithologic appearance in most of the sections of central Pennsylvania, but becomes increasingly argillaceous toward south central Pennsylvania as illustrated in Figure 9 and Figure 12. As the member thickens from Bellefonte to Shade Gap, the increase in argillaceous material occurs by addition of beds of abundantly argillaceous calcilutite rather

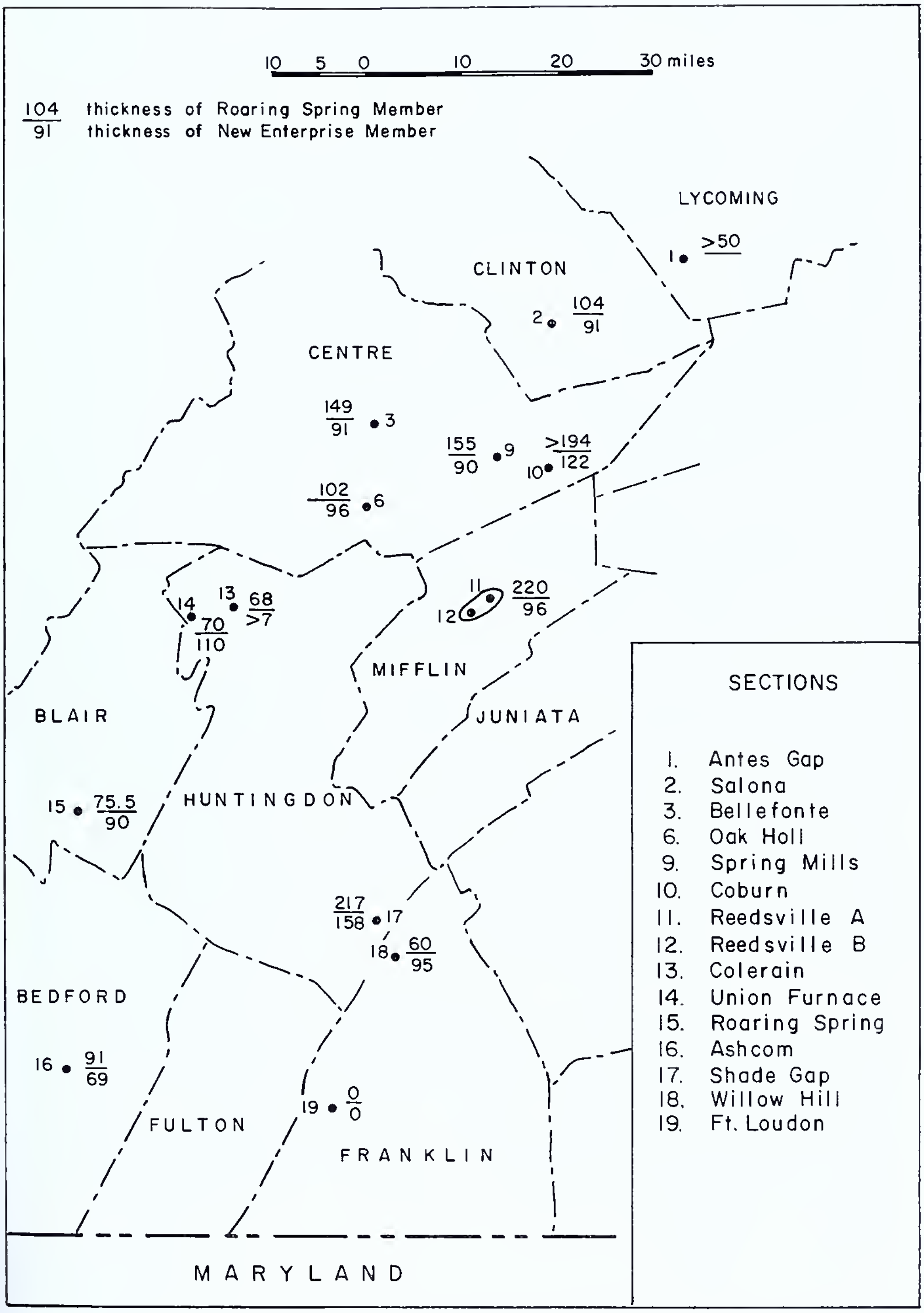

Figure 7. Thicknesses of the members of the Salona Formation at localities in central Pennsylvania

than by an increase in the number and thickness of calcareous shale interlayers. As shown in Figure 10, beds of abundantly argillaceous calcilutite first appear in the Roaring Spring Member at Spring Mills in a 28-foot rock unit which appears to continue southward to Reedsville in Kishocoquillas Valley. This rock unit is characterized at both localities by 1- to 2-foot interbeds of abundantly argillaceous calcilutite and is found in the 50-foot interval beneath the *Parastrophia hemiplicata* zone, but was not recognized in sections to the south. At Shade Gap, in Black Log Valley, about one-third of the Roaring Spring Member is composed of abundantly argillaceous calcilutite which occurs in rock units more than 20 feet thick.

The beds of the Roaring Spring Member become thicker toward the south where the member is more argillaceous. At sections in the northwestern part of the region, the beds of the Roaring Spring Member characteristically are 1 to 4 inches thick and contrast clearly with the 4-inch to 1-foot beds of the underlying New Enterprise Member. At Shade Gap in Black Log Valley, where much of the member is argillaceous, the beds generally are 4 to 8 inches thick and are quite similar in thickness to the beds of the New Enterprise Member. In general, many of the thin beds of the Roaring Spring Member lense out within the exposure, and some are undulose, whereas the thicker beds appear to be regular. Both bedding types are exhibited at Reedsville, the most complete exposure of the Roaring Spring Member north of the type section. At this locality, the lower and upper parts of the member are 1- to 4-inch bedded, whereas the middle part is 4-inch to 1½-feet bedded.

The dolomitic limestones of the Salona and Coburn Formations largely occur in the Roaring Spring Member where they generally are found in 1- to 4-inch bands below metabentonite layers. These bands are seen especially well beneath the thick metabentonite near the top of the member at Union Furnace, immediately below the metabentonite in the *Parastrophia hemiplicata* zone at Spring Mills, and between the *Parastrophia hemiplicata* zone and metabentonite R at Reedsville. The dolomitic limestones compose less than one percent of the Roaring Spring Member and do not appear to occur in a pattern that is regionally significant, although they generally are associated with metabentonite layers.

The Roaring Spring Member characteristically is very sparsely fossiliferous in all sections of central and south central Pennsylvania. In addition to *Parastrophia hemiplicata* and *Cryptolithus tesselatus*, which were discussed previously, the member mainly contains a few specimens of *Rafinesquina* sp., *Sowerbyella* sp., *Dalmanella* sp., *Parasopora* (?) sp., nautiloid cephalopods, linguloid brachiopods and trilobite parts and fragments. Burrow-like structures are common in some of the upper beds of the member, and a single occurrence of *Leptaena* sp. was found 26 feet above the base of the member at Reedsville. *Rafinesquina* sp. unid., a brachiopod with an extremely convex pedicle valve, occurs in the upper beds of the Roaring Spring Member as well as in the lower beds of the Milesburg Member and appears to follow their boundary except in sections in south central Pennsylvania. *Rafinesquina* sp. unid. was described by Schneider (1951) from the Waddle section as a new species in an unpublished Master's thesis, but the zonal range of the species has not been clearly established.

The upper part of the Roaring Spring Member is transitional and, where the Coburn Formation is present, contains a few widely-scattered interbeds of *Sowerbyella* bioskeletal calcirudite as well as numerous *Sowerbyella* sp. on some of the bedding surfaces.

Milesburg Member

The Milesburg Member of the Coburn Formation is characterized by beds of *Sowerbyella* bioskeletal calcirudite and *Sowerbyella*-trilobite bioskeletal calcirudite which occur in rhythmic alternations with calcarenites, calcilutites and calcareous shales. This member forms a wedge-like rock body that thins southward and eastward from Bellefonte and Salona as its lower beds are replaced at higher and higher levels by the upper beds of the underlying Roaring Spring Member (see Figures 9 and 10). As its lower boundary shifts upward, the upper boundary of the Milesburg Member remains parallel to metabentonite R over most of the region. South of Shade Gap in south central Pennsylvania, the Milesburg Member is absent and at Ashcom, in Bedford County, it is not identifiable with certainty. The thickness values of the member in the area of investigation are recorded on Figure 8.

The Milesburg Member at Bellefonte consists of two rock units, a lower unit characterized by interbeds of *Sowerbyella* bioskeletal calcirudite—sublithotype No. 1a—and an upper unit characterized by interbeds of *Sowerbyella*-trilobite bioskeletal calcirudite—sublithotype No. 1b. These rock units persist to most of the sections in the northwestern part of the region, but are not recognized south of a line between Reedsville and Roaring Spring where the Coburn Formation is thin and relatively uniform in character or is absent. The approximate occurrences of the units are shown in Figures 10 and 11 where the position of the lower rock unit is located by the occurrence of *Sowerbyella* bioskeletal calcirudites, designated letter S to the right of the geologic columns, and the approximate position of the

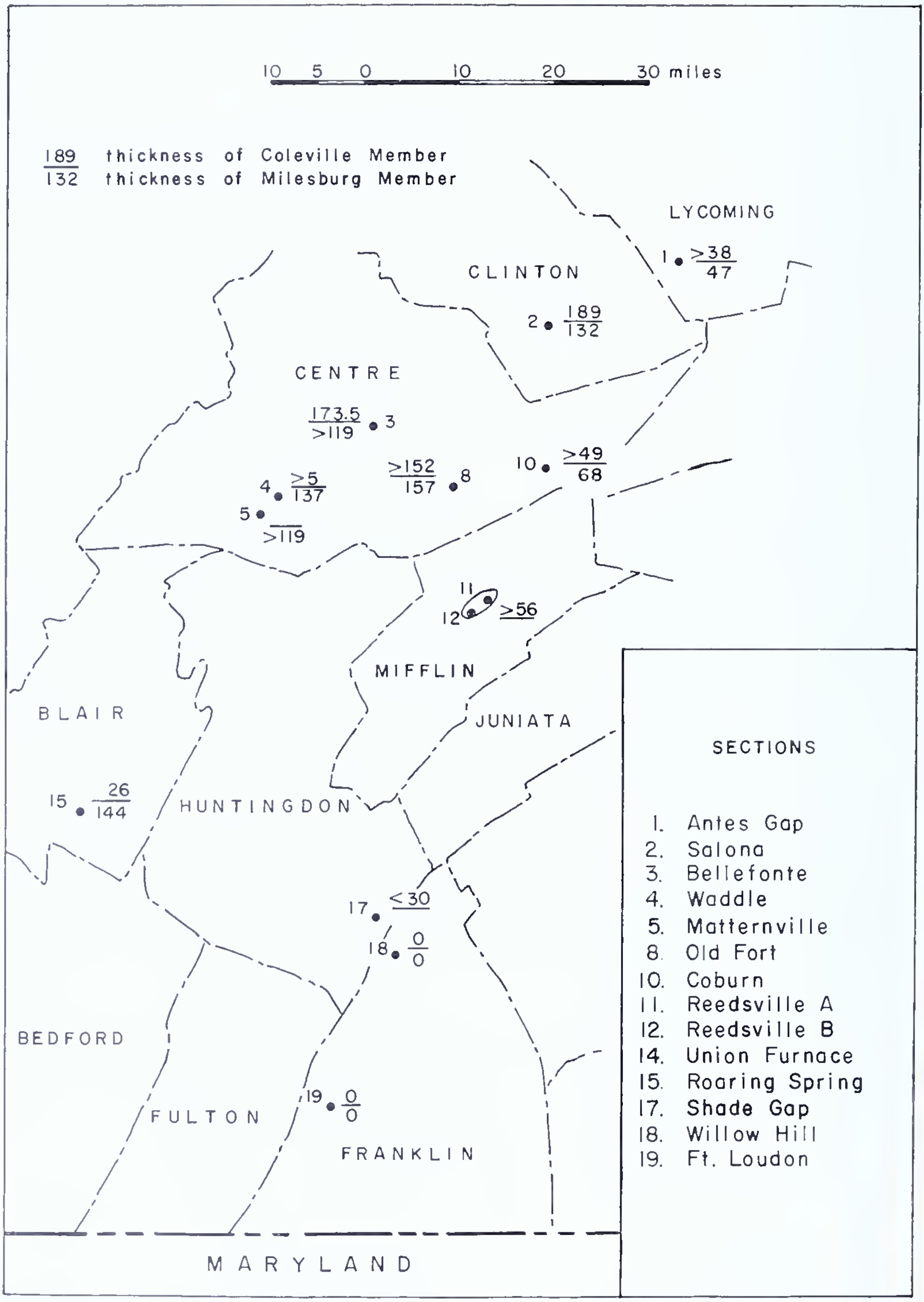

Figure 8. Thicknesses of the members of the Coburn Formation at localities in central Pennsylvania

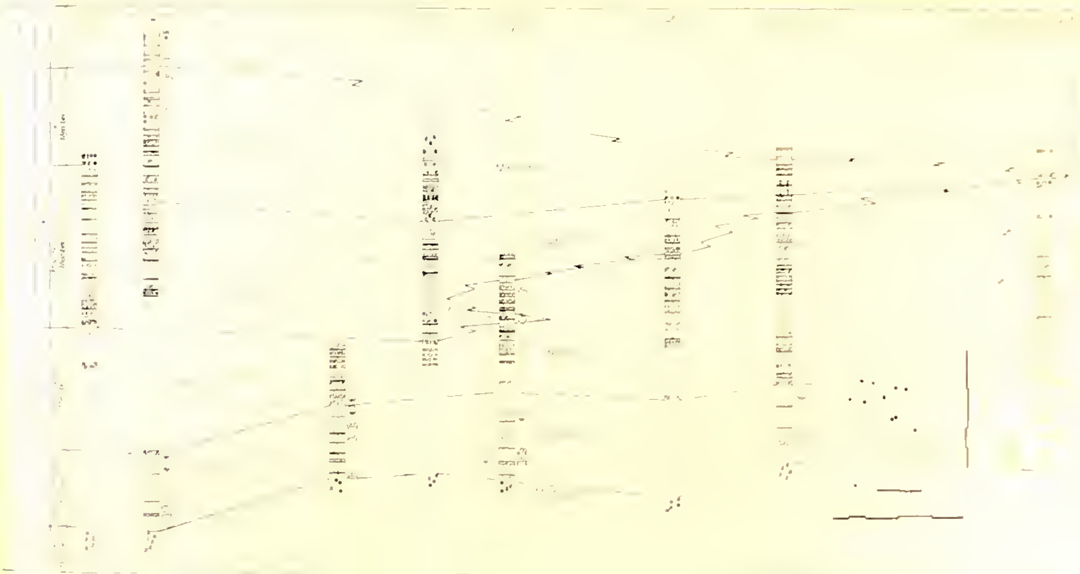

Figure 10. Stratigraphy of the [illegible] and [illegible] formations across [illegible] [illegible] Valley

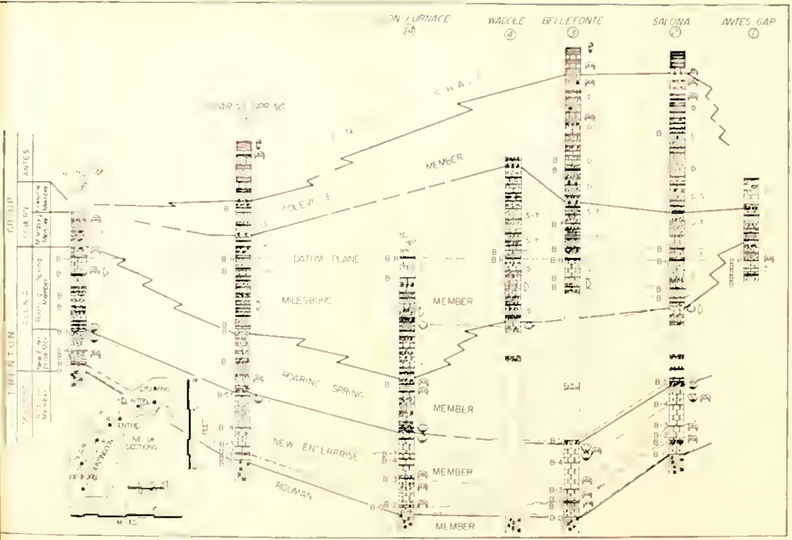

Figure 11 Stratigraphy of the Salona and Coburn formations along northern limb of Nittany Arch

Figur

upper rock unit is located by the occurrence of *Sowerbyella*-trilobite bioskeletal calcirudites, designated letters S-T.

In general, the lower rock unit of the Milesburg Member is confined to the interval below metabentonite R, and thins southeastward from about 75 feet at Waddle to about 15 feet at Coburn as its lower beds are replaced at gradually higher levels by the upper beds of the underlying Roaring Spring Member of the Salona Formation. Southwest of Bellefonte, the lower rock unit thickens to about 150 feet at Union Furnace as its lower boundary shifts downward, but thins again to about 35 feet at Roaring Spring. The upper unit occurs above metabentonite R and below the crinoidal beds which mark the base of the overlying Coleville Member and, in contrast to the lower unit, in most sections is a 50- to 70-foot rock body without significant variation in thickness.

The rhythmic alternations of bioskeletal calcirudite, calcarenite, calcilutite and calcareous shale which characterize the Milesburg Member at Bellefonte, the type locality, are recognizable everywhere in the region. These alternations commonly are less than 6 inches thick and typify both rock units wherever they are exposed.

The beds of bioskeletal calcirudite increase in number and thickness vertically, but most are impersistant laterally. In the lower rock unit of the Milesburg Member, these beds comprise about 10 percent of the rock sequence, commonly are less than 2 inches thick, and occur in lenses and stringers which are widely and irregularly spaced vertically, and laterally pinch out within 5 to 25 feet in the exposures. These beds comprise about 20 percent of the upper rock unit, are somewhat thicker and generally occur in individual beds which are more closely spaced and continuous in the exposures. In most sections, the 10- to 15-foot interval beneath metabentonite R is nearly devoid of bioskeletal calcirudites and is composed largely of argillaceous calcilutites—sublithotype No. 3a.

The calcarenites, which comprise about 50 percent of the Milesburg Member at Bellefonte, become less abundant southeastward at Old Fort and Coburn and southwestward at Roaring Spring, where they are replaced in the lower part of the member by argillaceous calcilutites. The calcilutites continue to increase in abundance as the member grades laterally into the underlying Roaring Spring Member.

Unlike the Salona Formation, the bedding thickness of the Milesburg Member is greatly variable both vertically and laterally, but has no apparent relationship to other regional changes. Beds less than 4 inches thick occur in some parts of the member, whereas other parts are composed of beds 6 inches to 1 foot thick. In general, these zones of bedding are not traceable to other sections.

Coleville Member

The Coleville Member of the Coburn Formation is characterized by interbeds of bioskeletal calcirudite that are rich in crinoid plates and species of *Dalmanella* and occur in rhythmic alternation with calcarenites, calcilutites and calcareous shales.

As shown in Figures 9 and 10, this member forms a wedge-shaped rock body that thins southeastward by interfingering with the overlying Antes shale, whereas its lower boundary parallels metabentonite R and the *Parastrophia hemiplicata* zone. This member also thins southward from Bellefonte as shown in Figure 11, but at Waddle the lower boundary occurs about 60 feet above its usual position. This deviation from parallelism may be accounted for either by the fact that the crinoidal bioskeletal calcirudite layers which mark the base of the Coleville member were not deposited in all parts of the region at the same time, or that the layers were deposited everywhere contemporaneously, and the rate of deposition varied from place to place.

The Coleville Member, like the Milesburg Member, is not recognized in sections south of Shade Gap and Roaring Spring, where it either is replaced entirely by the Antes shale or is indistinguishable from the Milesburg Member. The thickness values of the Coleville Member at localities in the region are shown on the map in Figure 8.

At Bellefonte, the Coleville Member is subdivided into three rock units on the basis of the fossil content of the bioskeletal calcirudites. The lower rock unit is characterized by numerous interbeds of crinoidal bioskeletal calcirudite—sublithotype No. 1c; the middle unit, a "mixed zone", contains subequal percentages of interbeds of *Sowerbyella* bioskeletal calcirudite—sublithotype No. 1a—and *Dalmanella* bioskeletal calcirudite—sublithotype No. 1e, and the upper rock unit is characterized by interbeds of *Dalmanella*-crinoidal bioskeletal calcirudite—sublithotype No. 1d—as well as *Dalmanella* bioskeletal calcirudite.

The rock units of the Coleville Member persist to all sections in the northwestern part of the region, but gradually disappear to the east and south as they are replaced at lower and lower levels by the shales of the overlying Antes. Because the Coleville Member thins from the top down, the lower rock unit geographically extends farther than the middle unit, which in turn extends farther than the upper unit.

The thicknesses of the rock units of the Coleville Member at sections in central and south central Pennsylvania are listed in Table 3. The Coleville Member is exposed completely at Salona, Bellefonte and Roaring Spring, and is exposed partially at several other localities. The approximate positions of the rock units are suggested on the

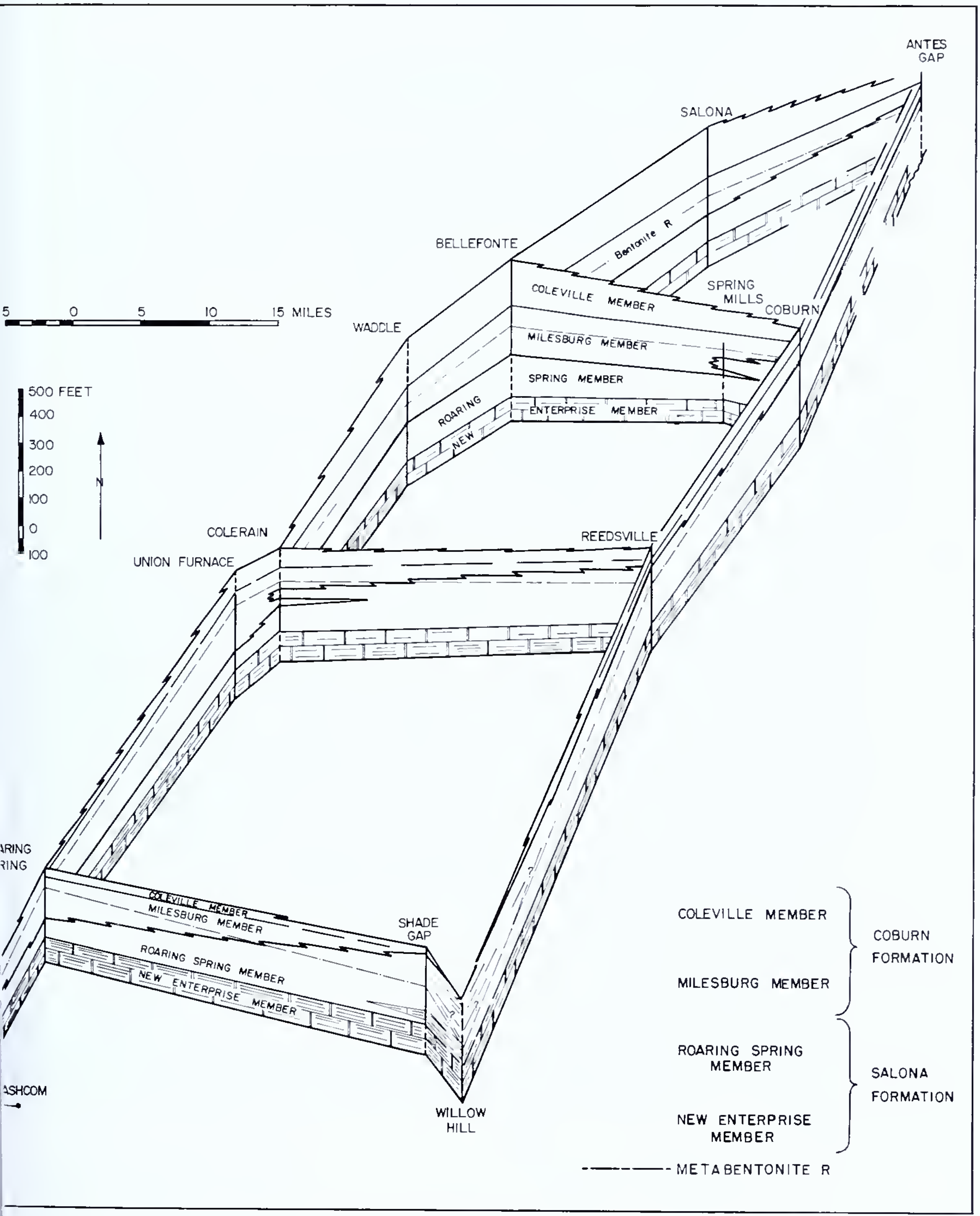

Figure 9. **Fence diagram of the Salona and Coburn Formations of central Pennsylvania**

stratigraphic diagrams of Figures 10 to 12 by the letter symbols of the sublithotypes of the bioskeletal calcirudites which are placed to the right of the geologic columns.

Table 3. *Thicknesses of rock units of the Coleville Member at localities in central Pennsylvania.*

Rock units of Coleville Member	Antes Gap	Salona	Bellefonte	Roaring Spring	Old Fort	Coburn	Reedsville	Shade Gap
Upper	37½	139	139½	0	95 +	24?	0	0
Middle	?	38½	25	25	5½	23	30 +	0?
Lower	½	12	9	1	51	2	?	5½ +

Evidence of the southward replacement of the upper rock unit of the Coleville Member by the Antes shale is presented in Figure 11. At Bellefonte and Salona, the upper rock unit is about 139 feet thick and contains abundant interlayers of *Dalmanella* and *Dalmanella*-crinoidal bioskeletal calcirudite. At Roaring Spring, the bioskeletal calcirudites which characterize the upper rock unit are absent, and the Antes shale lies comformably on the middle rock unit of the Coleville Member. In addition, *Cryptolithus tesselatus* occurs in the upper 60 feet of the Coleville Member at Bellefonte and Salona, but occurs at Roaring Spring from 50 to 70 feet above the base of the Antes shale. The trilobite *Triarthus beckii* occurs above the *Cryptolithus tesselatus* at all three localities.

Exposures are poor to the east of Bellefonte and Salona and the replacement of the upper rock unit of the Coleville Member cannot be clearly demonstrated in that direction. Apparently, the unit is absent at Coburn and Antes Gap where slope debris from rocks in the stratigraphic position of the upper rock unit is composed almost entirely of calcareous shale and very argillaceous limestone. The upper rock unit was not identified in sections southeast of Nittany Arch.

The middle rock unit of the Coleville Member extends beyond the geographic limits of the upper rock unit and is recognizable southward at Roaring Spring and southeastward at Reedsville. This unit is from 20 to 40 feet thick in the area of its exposure, except at Old Fort where it is only 5½ feet thick. At this locality, most of the bioskeletal calcirudites characteristic of the middle rock unit appear

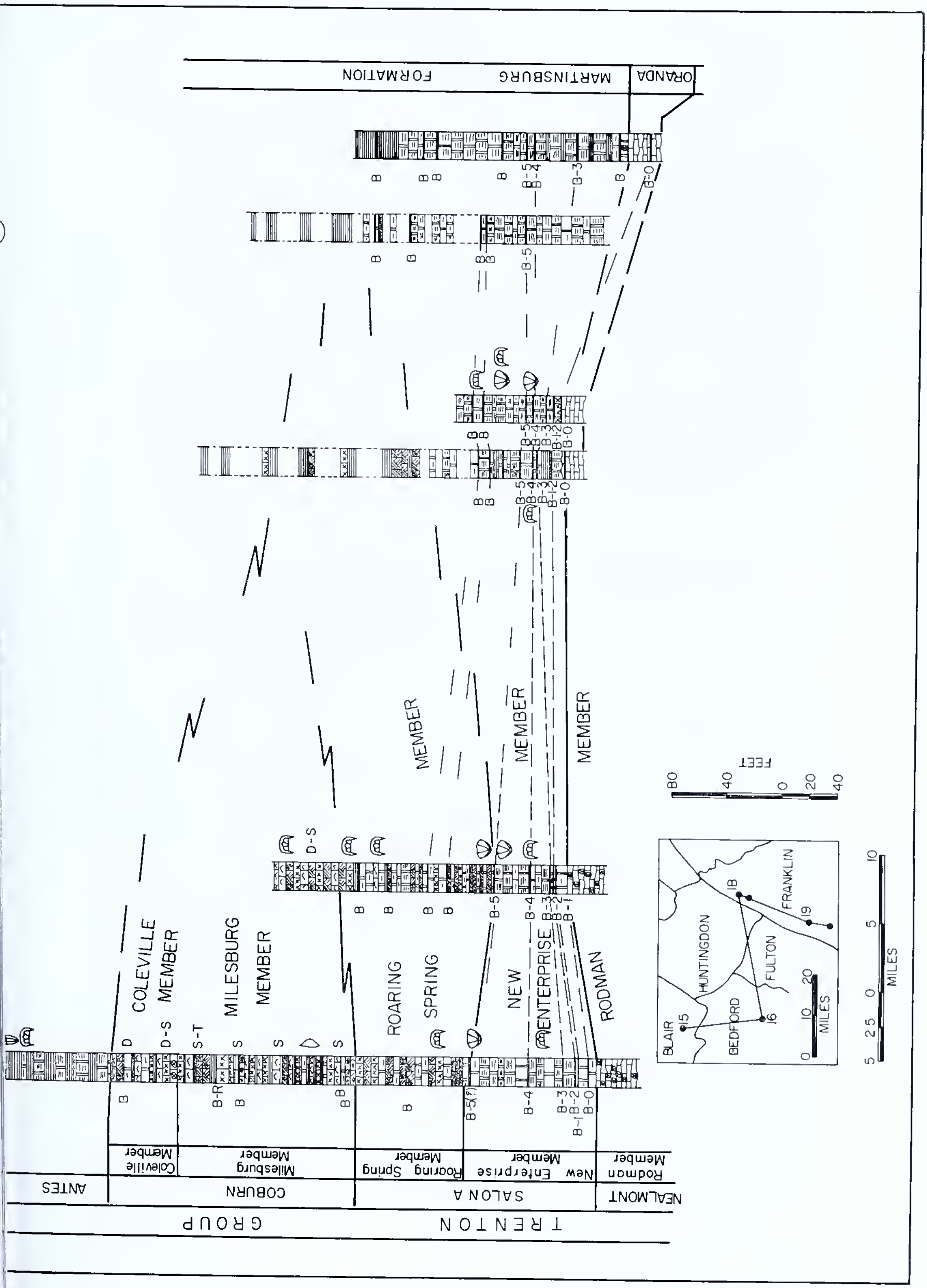

Figure 12. Stratigraphy of the Salona and Coburn Formations from southern Blair County to Franklin County

to be replaced by the crinoidal bioskeletal calcirudites of the underlying lower rock unit. At Old Fort, the Coleville Member contains a comparatively large percentage of crinoidal debris.

The lower rock unit of the Coleville Member is recognizable in all parts of the region except at Ashcom and in sections south of Shade Gap where the Coburn Formation is absent. This unit is less than 12 feet thick except at Old Fort, thins eastward and southward from Bellefonte and Salona, and parallels metabentonite R over most of the region. At Antes Gap and Roaring Spring, this unit is represented by single beds of crinoidal bioskeletal calcirudite less than 1 foot thick. Because of their position with respect to metabentonite R, these thin beds are considered to be a continuation of the lower unit. At Old Fort, the lower rock unit is 50 feet thick and possibly replaces some of the beds of the overlying middle rock unit.

The relationship of the lower rock unit to metabentonite R suggests that the unit was deposited contemporaneously throughout its extent.

PETROGRAPHY AND GENESIS OF IMPORTANT LITHOTYPES OF THE SALONA AND COBURN FORMATIONS

INTRODUCTION

The rocks of the Salona and Coburn Formations were classed into six lithotypes and eleven sublithotypes, as listed in Table 1. The lithotype groups include bioskeletal calcirudites, calcarenites, calcilutites, dolomitic limestones, calcareous shales, and metabentonites. About 75 thin sections and more than 250 etched surfaces from representative samples of the limestone lithotypes were studied in order to better understand their compositions and textures as well as to arrive at hypotheses of their modes of origin. In addition, about 15 heavy mineral separations from the metabentonites and more than 400 insoluble residues from the limestones were examined.

The samples were selected to represent the central tendency and variation within each group, as observed megascopically. Additional samples were taken more or less randomly from each group in order that variations which were not megascopically visible might be represented.

The results of the petrographic investigations are reported in the following discussion, beginning with a description of the morphological types of minerals observed in the thin sections, then progressing to consideration of the occurrences of the minerals as grains, matrix and cement in the rock types, and finally to consideration of hypotheses about the modes of origin of the important lithotype groups and of the rhythmic deposits.

The percentages reported in the following discussion were visually estimated from thin sections.

MORPHOLOGICAL TYPES OF MINERALS

The rocks of the Salona and Coburn Formations predominantly are composed of calcite, with subordinate percentages of clay and quartz and smaller percentages of other minerals. Several of the mineral varieties in these rocks are divisible on the basis of thin section and insoluble residue studies into morphological types. The minerals and their morphological types are listed in Table 4, and are discussed in the following pages.

Table 4. *Morphological Types of minerals in the rocks of the Salona and Coburn Formations.*

- Carbonate Minerals
    - Calcite
        - Non-bioskeletal calcite
            - Microcrystalline calcite
            - Sparry calcite
        - Bioskeletal calcite
    - Dolomite
        - Idiomorphic dolomite
        - Xenomorphic dolomite
- Non-carbonate Minerals
    - Quartz
        - Unit quartz crystals
        - Quartz aggregates
            - Fibrous quartz aggregates
            - Coarse quartz-crystal aggregates
            - Microcrystalline quartz aggregates or chert
            - Microcryptocrystalline quartz
    - Feldspar
    - Heavy Minerals

In addition to minerals, two morphological types of organic matter were observed in the thin sections of the studied limestones. These types include large organic (?) particles and disseminated organic matter.

Carbonate Minerals

Calcite

The calcite in the rocks of the Salona and Coburn Formations is divisible into two general types, namely, non-bioskeletal calcite, which forms the bulk of the limestones, and bioskeletal calcite. Several morphological subtypes were recognizable in each of these types.

A. *Non-bioskeletal calcite.* The two morphological subtypes observed in non-bioskeletal calcite are microcrystalline calcite and sparry calcite. Microcrystalline calcite occurs in grayish or brownish aggregates, presumably colored by included clay or organic matter. The bulk of the calcite crystals in this subtype are minute, commonly appearing to be less than 10 microns in diameter, with only small percentages as large as 20 microns. These crystals generally are not resolvable under the petrographic microscope.

Non-bioskeletal microcrystalline calcite comprises the bulk of the calcilutites of the Salona and Coburn Formations, as well as the pellets and the matrix of some of the calcarenites and bioskeletal calcirudites.

Non-bioskeletal sparry calcite, in contrast to the non-bioskeletal microcrystalline calcite, is clear and commonly occurs as polysynthetically twinned crystal aggregates in which crystal boundaries tend to be well-defined. The crystals in this type of calcite generally average more than 30 microns in diameter. The term microsparry calcite is here used where dimensions average 20 to 50 microns, and megasparry calcite where dimensions average greater than 50 microns.

Non-bioskeletal sparry calcite characteristically occurs as fillings of intergranular spaces, cavities in or beneath fossil specimens, and fractures. In bioskeletal calcirudites which contain very little matrix, many crinoid plates are enlarged by overgrowths of megasparry calcite, and a few of the other fossil fragments have "coronas" or rims of elongate megasparry calcite crystals that are oriented perpendicular to the perimeter of the shells. The overgrowths are in optical continuity with the crinoid plates, and polysynthetic twinning commonly extends through both the overgrowth and the crinoid plate nucleus.

Microsparry calcite is most commonly observed as intergranular cement in the fine-grained calcarenites. The microsparry calcite in these rocks furnishes reflecting surfaces for light and thus does much to provide the "crystallinity size" referred to in the field descriptions.

B. *Bioskeletal calcite.* This type of calcite includes the calcite observed in fossil remains. It ranges in morphologic type from the comparatively structureless microcrystalline form of trilobite and ostracode specimens, to the fibrous calcite of the brachiopods, the large unit crystals of crinoid and perhaps cystoid plates, and the coarse-crystal-aggregates of recrystallized molluscan shells.

In comparison to the relatively clear calcite in the brachiopod and recrystallized molluscan shells, the microcrystalline calcite in the trilobites commonly is tan in color, possibly owing to minute inclusions of organic matter. Some of the trilobite specimens contain dark rod-like structures which in cross-sections of the exoskeleton are seen to extend perpendicular to the surface. These rods may be fillings of original perforations of the shells or perhaps are special growth features.

The crinoid plates internally exhibit optical continuity and tend to contain numerous dark inclusions which give the plates a grayish or slightly brownish cast and distinguishes them from other types of coarse sparry calcite.

Fossil types other than those mentioned above are recognizable in the studied limestones, but do not constitute a volumetrically important part of the rock.

Dolomite

Insofar as observed in thin sections, dolomite forms a minor constituent of the Salona and Coburn limestones. Two distinct types of dolomite have been recognized, namely, idiomorphic dolomite and coarse xenomorphic dolomite (after Folk, 1952).

A. *Idiomorphic dolomite.* This type of dolomite occurs as idiomorphic to hypidiomorphic, rhombic crystals which usually are fairly widely-separated and are embedded in a matrix of microcrystalline calcite. The crystals characteristically contain sparse, minute, dark inclusions, and range in size from about 10 microns to about 50 microns. These crystals seem to represent dolomitization of the microcrystalline calcite matrix (Plate 9, Figure 6).

B. *Xenomorphic dolomite.* The crystals of this dolomite type do not show good rhombic form (Plate 9, Figure 7), but otherwise are similar in character to idiomorphic dolomite. These dolomite crystals generally contain a few dark, minute inclusions and are subequant with fairly smooth borders. Coarse xenomorphic dolomite is abundant in the dolomitic limestones, and more rarely is observable as fillings of some fossil cavities and the central portions of worm-burrow-like structures.

Non-Carbonate Minerals

Quartz

Quartz is a major constituent in insoluble residues from the Salona and Coburn limestones and may comprise as much as 25 percent of a few of the calcilutites and calcarenites. Two distinct morphological types of quartz, unit quartz particles and quartz aggregates, were recognized in the studied thin sections. The latter type is divisible into several important subtypes.

A. *Unit quartz particles.* Unit quartz particles, measuring about 40 microns to 80 microns in length, occur largely in the calcirudites and calcarenites of the studied rocks. These particles in general are singly or doubly terminated crystals, in many instances with the surfaces etched by growth of adjacent calcite. The crystals are clear, without observable quartz-grain nuclei, and much of the volume of individual crystals appears to be authigenic.

Less abundant unit quartz particles include larger singly or doubly terminated crystals, measuring as much as a millimeter or more in length, as well as conchoidally fracturing, irregular particles, up to 0.5 millimeters in diameter. Both of these types probably originated as fillings of cavities or veins.

B. *Quartz aggregates.* Several subtypes of quartz aggregates, differing in particle size as well as mode of origin, are recognizable in the limestones of the Salona and Coburn Formations. These include, in order of increasing particle size, microcryptocrystalline quartz, microcrystalline quartz or chert, fibrous quartz, quartz crystal aggregates and chert nodules.

Microcryptocrystalline quartz, as here understood, is a quartz aggregate composed of particles so small that most of them cannot be resolved at the largest magnifications of a petrographic microscope. The occurrence of this constituent first came to the attention of the writer in the study of insoluble residues. Some of the residues are composed almost entirely of extremely resistant aggregates which have retained the shape and angularity of the original limestone chips before the carbonate was removed by hydrochloric acid (Plate 7, Figure 1). Because of their resistance, the aggregates were presumed to be comprised, at least in part, of a siliceous material. Where viewed in reflected light in uncovered thin sections from which the carbonate had been removed, this type of quartz aggregate occurs as a brittle, fused-appearing network which apparently acts as a binding material in the rock. If the microcryptocrystalline quartz is multicrystalline, as are other chert types, the great majority of the individual particles must be less than a few microns in maximum dimension.

In almost all cases, microcryptocrystalline quartz occurs in association with carbonate and a brownish staining material which possibly is organic matter. Because of this association, microcryptocrystalline quartz generally is recognizable on hand specimens and etched surfaces as darker patches in the limestone matrix. It is especially common in fillings of worm-burrow-like structures in the calcarenites and calcilutites (Plate 10, Figures 1 to 8).

Microcrystalline quartz or chert is perhaps the most distinctive of the quartz aggregates and occurs almost exclusively in the form of chert plates comprised of microscopically visible particles which generally exhibit pin-point extinction under crossed nicols (Plate 7, Figures 5, 6, 13). The chert plates contain included quartz crystals, up to 50 microns in length, which generally are sparse, but in some instances are numerous and give the plates a much coarser appearance. The plates commonly are as thick as one quartz crystal, and some are partly opaque, possibly owing to a considerable amount of included organic matter.

Chert plates of microcrystalline quartz are very common in insoluble residues from some of the bioskeletal calcirudites, where they have been observed to be replacements of the outer layers of trilobite exoskeletons or as total replacements of ostracode shells, but have not been seen in other fossils.

Less common subtypes of quartz aggregate include fibrous quartz and aggregates of quartz crystals. Fibrous quartz is observed in thin sections to represent replacements of parts of brachiopod shells and pelmatozoan plates. The aggregates of quartz crystals are comprised of crystals, generally larger than one-half millimeter, which are cemented by quartz and probably represent cavity fillings. Aggregates of smaller crystals are rarer and possibly occur where crystals locally were crowded in laminae in which they tend to occur, as well as in cavity fillings.

In addition to above-mentioned occurrences, quartz has been observed in the Salona and Coburn Formations in the form of rare black chert nodules, up to 2 inches in diameter, as well as in a few bands which are less than 3 inches thick.

Feldspar

The feldspar crystals in thin sections of the rocks of the Salona and Coburn Formations commonly exhibit Carlsbad twinning and generally have a characteristic twin-crystal shape, as shown in Plate 7, Figure 14. Where twinning is lacking, feldspar crystals in some cases can be distinguished from quartz crystals by their stubbier and wider shape and general lack of parallel extinction. The feldspar crystals, like the quartz crystals, commonly are doubly terminated, lack observable feldspar-grain nuclei and exhibit various degrees of replacement by adjacent calcite. In accordance with these observations, it is suggested that most of the individual crystals of feldspar are authigenic.

The feldspar crystals found in the heavy residues from metabentonite No. 3 are clearly zoned (Plate 7, Figure 12) and appear quite different from those described above.

Heavy Minerals

Heavy mineral separations were prepared in bromoform from 15 metabentonite and 5 limestone samples. In general, the separations from metabentonite layers contain variable percentages of biotite, apatite and zircon, all of which tend to be euhedral. Separations from the limestones generally lack the above-mentioned heavy minerals, but contain an abundance of pyrite.

Organic Constituents

The organic constituents in the limestones of the Salona and Coburn Formations may be classed either as large organic (?) particles or as disseminated organic matter. The total amount of organic matter is directly related to the color of the limestones.

A. *Large organic (?) particles.* Several black, conchoidally-fracturing particles, up to one millimeter in diameter, were observed in insoluble residues from the studied limestones, and first were suspected to be particles of volcanic glass. However, these particles shown in Plate 7, Figure 4, are brittle, break down under pressure on a probe and are not transparent along their edges. Although positive identification of the particles has not been made, it is suggested that they are organic in composition.

B. *Disseminated organic matter.* This type of organic matter is not directly observable under the microscope, but presumably is present as minute inclusions in sparry calcite and in association with the clay in the Salona and Coburn rocks.

In order to demonstrate the relationship of the percentage of organic matter to the colors of the insoluble residues and hand specimens, five insoluble residues, ranked from lightest to darkest, were analyzed chemically for percent carbon. Results of the analyses are shown in Table 5.

Table 5. *Relationship of the percentage of carbon to the colors of insoluble residues from the Salona and Coburn limestones*

Relative Color of Insoluble Residue	Sample No.	Percentage of carbon in residue	Percentage of residue in rock	Calculated percentage of carbon in rock
light gray	1	0.30	35.32	0.11
medium gray	2	1.21	18.95	0.23
	3	0.90	20.84	0.19
dark gray	4	1.34	29.48	0.40
black	5	3.94	21.55	0.85

The amount of carbon in the residues ranged from 0.30 percent to 3.94 percent, the higher percentage representing the darker residue. On the basis of the total amount of residue in the limestone sample, the total percent of carbon in the rock was calculated as shown in the right-hand column of Table 5. These results indicate that, in general, the percentage of carbon increases in the darker residues. After burning, the remaining residues all were lighter in color than the lightest-colored residue before burning.

In order to demonstrate the relationship of the colors of the insoluble residues, and therefore the percentage of organic matter, with the colors of the hand specimens of limestones from the Salona and Coburn Formations, the residue colors and hand specimen colors of 118 samples from the Roaring Spring section were plotted on a contingency table and tested for independence by a chi square (X^2) test according to procedures described by Dixon and Massey (1951). The observed and expected values for the tested specimens are recorded in the contingency table in Table 6, where the expected values are enclosed in parentheses. As indicated in the Table, the colors of both the residues and the hand specimens were classed merely as light, medium or dark. In comparison with the color chart distributed by the Geological Society of America, the term light approximately corresponds to medium gray, medium to dark gray and dark to grayish black.

Table 6. *Contingency table comparing colors of insoluble residues with colors of hand specimens of limestones from the Salona and Coburn Formations at Roaring Spring.*

Rock Colors	Residue Color			Total
	Light	Medium	Dark	
Light	8 (3)	8 (5.5)	3 (10.5)	19
Medium	9 (6)	18 (10.5)	9 (19.5)	36
Dark	2 (10)	8 (18)	53 (35)	63
Total	19	34	65	118

The X^2 value for the above data is 48.55. For 4 degrees of freedom, (rows—1) (columns—1), $X^2_{.995}$ equals 14.86. Because the X^2 value for data shown in the contingency table is much larger than 14.86, the hypothesis of independence is rejected at the 0.5 percent level of significance. Conversely, it is concluded that the residue colors and hand specimen colors are dependent, and that light-colored limestones tend to have light-colored insoluble residues, whereas dark-colored limestones tend to have dark-colored residues. Inasmuch as the darkness of the colors of the insoluble residues was shown previously to be provided largely by organic matter, it is also concluded that the percentage of organic matter provides the dark colors of the hand specimens. This may indirectly reflect the amount of clay in the limestones, as organic matter is reported to be commonly associated with clay.

Insoluble Residues

Samples for insoluble residue studies were collected at a three-foot interval from a continuous 365-foot exposure of the Salona and Coburn Formations in the New Enterprise Company quarry, section No. 15 in Figure 2. Each sample was prepared for study according to the method described by Thompson (1958) in which the sample is crushed to chips, homogenized and dissolved in several treatments of dilute hydrochloric acid. The fines were decanted off and only the coarse fractions were studied.

The components recognized in the coarse fractions of the studied insoluble residues include the non-carbonate minerals described above, as well as fine-grained aggregates composed of variable percentages of clay and microcryptocrystalline quartz. The aggregates were subdivided into siliceous aggregates (Plate 7, Figure 1), argillaceous-siliceous aggregates (Plate 7, Figure 2) and argillaceous aggregates (Plate 7, Figure 3). These groups of aggregates were distinguished from each other by their resistance to breakage when tested with a probe, their ability to retain the shape of the original limestone chips before solution in acid and the presence or absence of fossil molds.

The Coburn Formation as a whole and the members of the Salona Formation can be distinguished from each other on the basis of their insoluble residues, but members of the Coburn are inseparable by this study. The New Enterprise Member of the Salona Formation is characterized by residues containing large percentages of argillaceous aggregates and generally lacking in the various quartz and chert types. In contrast, many of the residues from the Roaring Spring Members of the Salona Formation contain appreciable percentages of quartz crystals, as well as large percentages of argillaceous aggregates.

The residues of the Coburn Formation are quite variable in composition, reflecting the cyclic nature of occurrence of rock types in it. However, some of these residues contain chert plates and irregular aggregates of quartz which probably were derived from silicified fossil parts and therefore are rare or absent from the sparsely fossiliferous Salona Formation.

The study of the insoluble residues lends support to the field study primarily because each of the limestone lithotypes has a characteristic insoluble residue. Residues from the calcilutites tend to contain large percentages of argillaceous aggregates and very little of anything else. Residues from the calcarenites generally contain appreciable percentages of quartz crystals, and those from the bioskeletal calcirudites contain chert plates and irregular quartz aggregates derived from silicified fossil parts, in addition to quartz crystals.

Siliceous aggregates, presumably containing large percentages of microcryptocrystalline quartz, occur in the New Enterprise Member only in residues obtained from limestones adjacent to metabentonite layers. In the Roaring Spring Member and in the Coburn Formation, these aggregates are scattered throughout the sequence and are not entirely related to the metabentonite layers. In both cases, the silica in the aggregates probably was derived from the devitrification of bentonitic materials. However, the bentonitic materials probably were not preserved as layers in many parts of the Roaring Spring Member and in the Coburn Formation, where the sediments are cyclical and shown signs of having been reworked before final deposition.

Petrography of Important Lithotypes

The thin-section studies of the rocks of the Salona and Coburn Formations were concentrated almost entirely on samples from those limestone lithotypes which are important volumetrically in the rock sequence. These lithotypes include the bioskeletal calcirudites, calcarenites and calcilutites. At least 20 thin sections were prepared from each lithotype group.

In the discussions of each lithotype group, principal consideration is devoted to the occurrence of previously described morphological types of minerals in the forms of grains, matrix or cement. The terms grains, matrix and cement, as used in this discussion, are relative terms which conform to the definitions provided by Krynine (1948). According to this usage, the term grain is intended for individual particles of sedimentation. If the particles in a rock are of different orders of magnitude, the larger particles are considered to be grains, and the smaller particles filling intergranular spaces are considered to be matrix. Where larger particles are absent from a rock, the smaller particles are termed grains, and matrix is not considered to be present. Cement is an authigenic precipitate that fills intergranular spaces.

In the limestones of the Salona and Coburn Formations, the matrix generally is comprised of intermixed microcrystalline calcite and argillaceous material. Whether this material occurs as matrix or as grains, it is here termed "argillaceous lime mud".

In addition to the calcirudites, calcarenites and calcilutites, brief mention is made in the present section of the dolomitic limestones and of heavy mineral separations from bentonite layers.

Bioskeletal Calcirudites

The bioskeletal calcirudites of the Coburn Formation are composed dominantly of fossil remains that either are cemented together by megasparry calcite or are embedded in a matrix of intermixed microcrystalline calcite and argillaceous material (argillaceous lime mud). Fossil remains comprise at least 75 percent of the grains of the bioskeletal calcirudites and at least 20 percent of the total rock. The fossils principally are parts of brachiopods, trilobites and crinoids with subordinate percentages represented by other fossil groups. They occur in all degrees of fragmentation and range in size from unbroken brachiopod valves, larger than an inch in diameter, to ostracode shells and minute fragments, much less than a millimeter in maximum dimension. Subordinate types of grains in the calcirudites include pellets and crystals of feldspar and quartz, and rare large fragments of lime mud, up to a centimeter in diameter. These types are much more abundant in the calcarenites and are discussed more fully there.

The bioskeletal limestones with little argillaceous lime mud as matrix generally are composed of fragmented brachiopod valves and crinoid plates cemented by megasparry calcite. Megasparry calcite occurs in these rocks as overgrowths of crinoid plates, coronas on a few of the brachiopod valves and fillings of intergranular spaces. Pellets, possibly fecal pellets, are scattered among the fossils and comprise more than 10 percent of the grains in a few samples. These "clean" bioskeletal layers generally contain less than ten percent of insoluble residue and are especially common in the lower one-half of the Coleville Member.

Bioskeletal calcirudites with an abundance of argillaceous lime mud as matrix are uncommon in the Coburn Formation but generally are found in the Milesburg Member. These calcirudites commonly are composed of unfragmented brachiopod valves and trilobite parts, and small percentages of crinoidal material, all of which are embedded in argillaceous lime mud. In rare cases, unfragmented and unseparated brachiopod values and trilobite exoskeletons were observed. Nonbioskeletal sparry calcite is rare in these limestones and generally occurs as cavity fillings beneath or within fossil specimens. The cavities beneath some of the convex brachiopod valves probably represent cavities that were present at the time of deposition.

Many of the fossil specimens in some of the bioskeletal calcirudites are partly silicified or pyritized. In such samples, the outer parts of trilobites and ostracodes are replaced by chert, which is seen in insoluble residues as chert plates, the bryozoans and the central parts of crinoid stem plates are replaced by massive quartz, and brachiopods by fibrous quartz. Pyrite cubes tend to be associated with the various forms of quartz, but also occur in unsilicified brachiopod shells or in calcite-filled cavities.

Microcryptocrystalline quartz is rarely present in the bioskeletal calcirudites in the form of patches or bands. Burrow-like structures which are common in some of the calcilutites and calcarenites are very rare in the bioskeletal calcirudites.

Calcarenites

The calcarenites of the Salona and Coburn Formations are composed largely of carbonate sand pellets and crystals of quartz and feldspar which are cemented by microsparry calcite. More rarely, the calcarenites contain fossil fragments and fragments of lime mud as grains, and various percentages of argillaceous lime mud as matrix.

The pellets are ovate or slightly elongate, very well rounded particles composed principally of microcrystalline calcite. The pellets range from about 50 microns to about 0.2 millimeters in maximum diameter, lack internal structures and are dark brown, possibly owing to an abundance of included organic matter. The boundaries of many of the pellets are ragged when viewed at high powers, possibly as a result of recrystallization into microsparry calcite. Pellets generally comprise from 25 percent to 50 percent of the fine-grained calcarenites, and occur most commonly in calcitic laminae in association with crystals of quartz and feldspar.

Illing (1954) and Beales (1956, 1958) indicate that pellets such as those described above are polygenetic and may be altered fecal pellets, pellets formed from skeletal grains, grains of accretion, composite grains, or grains derived from pre-existing rocks outside the basin of deposition. The writer favors local formation for the pellets of the Salona and Coburn Formations because (1) their loci of accumulation are at least 100 miles from the nearest source area, and (2) they are composed of carbonate which could not withstand long distance transportation. Accordingly, the pellets might be fecal pellets, grains of accretion or reworked and rounded particles of unconsolidated lime mud. The term bahamite is used by Beales (1958) for calcarenites whose grains are principally composed of pellets.

The authigenic crystals of quartz and feldspar, described previously, tend to occur in association with pellets in the more calcitic laminae and cross-laminae of the calcarenites (Plate 8, Figures 5 to 8 and Plate 9, Figure 1), and are much less abundant in other lithotypes. The crystals appear to be fairly uniform in size, comparable in size to the pellets, do not penetrate pellets or other types of grains, and exhibit various degrees of replacement by growth of adjacent calcite. In some thin sections, crystals of quartz and feldspar are concentrated near the bases of the calcarenites, above abrupt contacts, where they comprise as much as 20 percent of these parts of the rock and tend to occur with larger, rounded fragments of lime mud (Plate 8, Figure 8 and Plate 9, Figure 1). The above evidence seems to favor the hypothesis that the crystals grew elsewhere on the sea floor, perhaps in areas of lime mud, and then were transported by waves and currents with the pellets into their final place of deposition. It is possible, however, that some of the crystals grew in their present positions, possibly in more porous parts of the rocks.

The fossil remains in the calcarenites include small fragments of large fossils, as well as smaller fossils such as ostracodes, and juvenile specimens of mega-fossils. The fossil remains generally are much less than a millimeter in maximum dimension and commonly are not observable in hand specimens except on a few bedding surfaces. Fossils generally are very sparse in the calcarenites.

Rarer grains in the calcarenites include fragments of lime mud and crystals of pyrite. The fragments of lime mud generally are very well rounded and larger than one-half millimeter, and some contain pellets and crystals of quartz and feldspar. Lime mud fragments commonly are found in the basal parts of the calcarenites, immediately above scour surfaces as shown in Plate 8, Figure 8. Crystals of pyrite appear to have a distribution similar to that of the crystals of quartz and feldspar, but comprise much less than one percent of the rocks.

All gradations exist between calcarenites whose grains are cemented by microsparry calcite and calcarenites whose grains are embedded in a matrix of argillaceous lime mud with various percentages of microcryptocrystalline quartz (Plate 8, Figures 5, 6, 7).

Microcryptocrystalline quartz generally is evenly distributed throughout the rocks in which it occurs, but also was observed in scattered irregular patches and partial fillings of burrow-like structures. Microcryptocrystalline quartz commonly is associated with brownish-colored, organic (?) matter and therefore appears darker than the remainder of the rock, as depicted in Plate 10, all Figures, and in Plate 4, Figures 7 and 8. Where microcryptocrystalline quartz is abundant, insoluble residue may comprise more than 35 percent of the rock.

The above-mentioned burrow-like structures, presumably produced by worms or other burrowing animals, are irregular, tubular structures that usually are less than 5 millimeters in diameter, extend through the rocks subparallel to bedding for at least several inches, and transect previous sedimentary structures (Plate 10, all Figures). Because they generally are partly filled by microcryptocrystalline quartz and organic (?) matter, cross-sections of the burrows are visible on hand specimens as dark-color splotches. Some of the central portions of the worm burrows contain xenomorphic quartz crystals in addition to microcryptocrystalline quartz, as depicted in Plate 9, Figure 8, as well as in Plate 10, Figures 1, 4 and 7.

The laminae and cross-laminae, described in hand specimens as being composed of medium dark gray, silty limestone, comprise the dominant percentage of the calcarenites and, in thin sections, are composed primarily of grains of pellets, crystals of quartz and feldspar, fossil remains and fragments of lime mud which are cemented by microsparry calcite. The laminae of grayish black, more argillaceous limestone in the calcarenites are composed of argillaceous lime mud with only a few recognizable grains. The argillaceous laminae commonly are sparse near the bases of the calcarenites, but increase in number as the calcarenite grades upward into calcilutite.

Calcilutites

The calcilutites of the Salona and Coburn Formations dominantly are composed of argillaceous lime mud and included patches of microsparry calcite, whereas pellets, fossil remains and other larger grains are rare. The textural components of the calcilutites generally are distributed homogeneously, and the rock appears structureless (Plate 9, Figures 2 and 4).

The patches of microsparry calcite in the calcilutites may in part arise from precipitation in voids in the sediments, recrystallization of lime mud or total replacement of crystals of quartz and feldspar. These patches apparently provide much of the crystalline fraction seen in hand specimens.

A few pellets and crystals of quartz and feldspar are found in the coarser calcilutites and in general are smaller than those observed in the calcarenites. Most of the fossils in the calcilutites are fragmented. Small, but unfragmented fossils might represent juvenile specimens of normally larger fossils, or might be specimens of totally different minute species.

The subdivision of the calcilutites into argillaceous calcilutites—sublithotype No. 3a—and abundantly argillaceous calcilutites—sublithotype No. 3b—is not clear in thin section studies. Most of the calcilutites contain some opaque material, submicroscopic in size, that probably consists largely of clay which is colored by disseminated organic matter. In some thin sections of the abundantly argillaceous calcilutites, clay is relatively more abundant and in rare instances occurs in distinct partings or laminae (Plate 9, Figure 3).

The insoluble residues from calcilutites that occur adjacent to bentonite layers commonly are composed almost entirely of siliceous aggregates which presumably are composed in part of microcryptocrystalline quartz. The occurrence of microcryptocrystalline quartz in the calcilutites is similar to the occurrence in the calcarenites. Xenomorphic dolomite was observed in the central portions of burrows, and pyrite is generally evenly distributed throughout the calcilutites.

Metabentonites

The metabentonite layers seldom are found in an unweathered condition and, like the calcareous shales, were not observed in thin section. Instead, several heavy mineral separations were prepared from the metabentonite layers in the Salona and Coburn Formations at Roaring Spring in order to compare newly discovered metabentonite layers with those described by previous workers.

The heavy mineral separations from most of the metabentonite layers characteristically contain euhedral crystals of biotite, apatite and zircon which occur in various percentages and in rare instances exhibit some rounding. In general, separations from metabentonite No. 0 to metabentonite No. 5, represented in Plate 7, Figure 16, contain an abundance of biotite which occurs in association with well-formed crystals of apatite and zircon. Metabentonite No. 3 at Roaring Spring additionally contains an abundance of zoned crystals of feldspar (Plate 7, Figure 12), but no attempt has been made to trace this occurrence to other localities. The separations from metabentonites which occur higher in the rock sequence contain smaller percentages of biotite which in some cases occur with fairly well-rounded crystals of apatite and zircon (Plate 7, Figure 1), indicating some movement before final deposition of the heavy minerals.

In contrast to the metabentonite layers, heavy mineral separations from the limestones are characterized by large percentages of pyrite and generally lack apatite, zircon and biotite. In one sample, biotite was observed standing in relief on an etched surface of a calcarenite.

Additional information on the heavy mineral assemblages and clay-mineral composition of metabentonites No. 0 to No. 5 is provided by Bonine and Honess (1928), Rosenkrans (1934) and Weaver (1953).

Dolomitic Limestones

The dolomitic limestones of the Salona and Coburn Formations dominantly are composed of xenomorphic dolomite that is concentrated in laminae and cross-laminae in association with very fine opaque material which presumably is organically-colored clay. The dolomitic laminae alternate with more argillaceous laminae, without dolomite, as depicted in Plate 9, Figure 7. Where viewed at large magnifications, the individual dolomite crystals do not occur in an interlocking mosaic, but are separated from each other by a thin thread of opaque, organically-colored clay, and the crystal boundaries appear irregular or abraded. This distribution of distinctly separated crystals of xenomorphic dolomite might result from (1) dolomitization of lime mud or of calcitic, more porous laminae, or (2) the redistribution of previously formed dolomite into laminae and cross-laminae as may be the case with the crystals of quartz and feldspar. In case (2), the crystals of dolomite would form the grains of the rock.

The dolomitic limestones generally are unfossiliferous and lack grains of pellets and crystals of quartz and feldspar. They are found in a few 1- to 4-inch bands in limestones adjacent to some of the metabentonite layers, and volumetrically are unimportant.

Mode of Origin of Common Limestone Lithotypes

The present discussion is an attempt to reconstruct the mode of formation of the bioskeletal calcirudites, calcarenites and calcilutites of the Salona and Coburn Formations, insofar as can be generalized from studies of hand specimens, etched surfaces, thin sections and insoluble residues. Special consideration is devoted to those attributes of the rocks which permit formulation of hypotheses about distances of transportation of the grains, current strengths and depths of water in which the grains were deposited, as well as about possible origins and times of emplacement of postdepositional components.

The modes of origin of the dolomitic limestones and of the metabentonites have been discussed previously and are not considered again in this section. The metabentonites are concluded to be products of altered volcanic ash. The xenomorphic dolomite that characterizes the dolomitic limestones may represent either dolomitized parts of earlier limestones or grains of dolomite that were distributed by currents or waves into laminae or cross-laminae.

Bioskeletal Calcirudites and Calcarenites

The bioskeletal calcirudites and calcarenites are similar in that both of them are composed of recognizable grains which generally are cemented by sparry calcite and less commonly are embedded in a matrix of argillaceous lime mud. Because of their compositional and textural similarities, the modes of origin of these rock types can be considered together, whereas the calcilutites, composed principally of lime mud, are discussed separately. The possible modes of origin of the bulk of the bioskeletal calcirudites and calcarenites may be as follows:

1. *Deposition of the grains.* The separation of the fossil remains into parts, the presence of rounded fragments of lime mud, the occurrence of these and other grains in laminae, cross-laminae and graded beds, with scour surfaces beneath some of the beds, all indicate that the grains of the bioskeletal calcirudites and calcarenites were moved about by bottom-currents before being finally deposited. In the bioskeletal layers, most of the fossils are separated into parts, but the parts are not greatly fragmented, suggesting that the fossils probably were moved for only short distances. The great abundance and variety of fossils in the Coburn Formation and their apparently short distance of transportation support the conclusion that organisms were living in profusion over much of the area of deposition.

Subordinate percentages of the fossil remains in the bioskeletal layers are minutely fragmented and are intermixed with fairly large, well-rounded fragments of lime mud, as well as with fossils whose cavities are filled with lime mud which differs from the matrix of the present rock. These features suggest a comparatively longer distance of transportation or more intense current activity, as well as some reworking of partly consolidated lime mud.

In contrast to those in the bioskeletal layers, most of the relatively few fossil remains in the calcarenites are broken into minute fragments that either may have been transported for relatively long distances or may constitute smaller particles that were derived from nearby concentrations of fossils. The unabraded condition of most of the crystals of quartz and feldspar in these rocks tends to favor a comparatively short distance of transportation.

The pellets in the calcarenites may indicate either a short or long distance of transportation, depending on their mode of origin. If the pellets are fecal pellets, those which occur in the calcarenites of the Roaring Spring Member must have been transported for considerable distances, inasmuch as layers with abundant fossils are absent from this member. If the pellets are fragments of lime mud or grains of aggradation, they may have formed in the same general locality in which they finally accumulated.

2. *Deposition of lime mud.* The bioskeletal calcirudites and calcarenites contain variable and usually small percentages of interstitial lime mud. The small amount of lime mud in these coarser-grained rocks may represent lag deposits that were not removed with the bulk of the lime mud by winnowing currents or waves, or mud that trickled down between the grains at later stages when the currents diminished in strength. In the latter case, the fossils and pellets would have accumulated in areas without lime mud. The movement of lime mud is indicated by the presence of "mud-stuffed" fossils and rounded fragments of lime mud, but these components are rare and perhaps should not be considered as criteria for hypothesizing the origin of the entire mass of lime mud.

Much of the lime mud probably precipitated as such, whereas lesser percentages may be composed of triturated fossil remains. The argillaceous material that generally is intermixed with the lime mud is detrital.

3. *Cementation by sparry calcite.* Coronas on some of the brachiopod fragments and overgrowths on some of the crinoid plates probably represent the first stages of cementation. In order for the delicate coronas to have been preserved, the grains probably had stopped moving and had assumed their more or less final resting places. Coronas and overgrowths generally are not found in calcirudites or calcarenites which contain appreciable percentages of lime mud.

Following the initial stages of cementation, the remainder of the interstices were filled with microsparry calcite in the case of the calcarenites and megasparry calcite in the case of the bioskeletal calcirudites. The size of the sparry calcite apparently was controlled by the size of the open voids. In view of the fact that most of the limestone layers are separated by impermeable shales which would inhibit the vertical passage of solutions through the rocks, it appears most likely that most of the sparry calcite formed at an early post-depositional stage, while the sediment still contained a large volume of calcium-charged water. This hypothesis is supported further by the fact that stylolites, which might permit lateral movement of solutions at a later stage, are absent from most of the limestone layers. Part of the sparry calcite cement might have formed by recrystallization of interstitial calcitic or aragonitic lime mud.

Calcilutites

The calcilutites, in contrast to the calcirudites and calcarenites, are dominantly composed of argillaceous lime mud. These limestones contain comparatively few recognizable grains and generally lack sedimentary structures, and were probably deposited in quiet water, either at depths below wave base or in shallow, protected areas.

The microcrystalline calcite which forms the bulk of the calcilutites might have been derived from (1) physical-chemical or biogenic precipitation from sea water at the site of final deposition, (2) trituration of fossil parts by current action, or (3) sorting of fine material from the grains of the calcarenites and calcirudites.

The calcilutites of the Salona and Coburn Formations may be divided into two types on the basis of their occurrence in the rock sequence, although samples from each type appear similar in hand specimens and thin sections. The first type comprises the New Enterprise Member which generally is about 100 feet thick, comparatively uniform in appearance, and without bioskeletal calcirudites or calcarenites. The second type occurs in rhythmic alternations which are commonly less than 10 inches thick, variable in appearance and with bioskeletal calcirudites and calcarenites. The two types of calcilutite may have different modes of origin.

Time of Formation and Origin of Quartz, Dolomite and Pyrite

There is evidence in the studied thin sections to indicate that some of the quartz, dolomite and pyrite in the calcirudites, calcarenties and calcilutites may have been deposited with the grains of the rocks, whereas other percentages of these constituents were introduced after the grains had assumed their more or less final resting place. A large percentage of the euhedral crystals of quartz and some of the pyrite cubes and xenomorphic dolomite crystals which occur in laminae and cross-laminae of the calcarenites in association with other grains of comparable size seem to have formed elsewhere on the sea floor before being moved by currents to their final place of deposition.

The postdepositional origin of quartz, dolomite and pyrite is indicated by (1) the fillings of burrow-like structures with microcryptocrystalline quartz and xenomorphic dolomite, (2) the occurrence of microcryptocrystalline quartz in scattered patches that seem to grade into the surrounding matrix, (3) the silicification and pyritization of fossil parts, (4) the replacement of lime mud by idiomorphic crystals of dolomite which also penetrate some adjacent grain boundaries, and (5) quartz fillings of fractures.

Except for the fracture fillings, much of the quartz, dolomite and pyrite described in the above paragraph may have begun to form at an early postdepositional stage, while the sediment was still soaked with sea water and while porous avenues through the rocks, such as worm burrows, were still open. The fillings of the burrows may represent either the excrement of the burrowing animals or the introduction of silica and dolomite while the furrows were still open and not cemented by sparry calcite. In either case, deposition of silica and dolomite in the burrows would probably occur at an early stage after the deposition of the grains. The time of the replacement of lime mud by idiomorphic dolomite and of fossil parts by quartz is difficult to establish in the postdepositional history of the rocks. The fractures probably were filled by quartz and calcite after the structural deformation of the entire rock sequence.

A large percentage of the quartz and dolomite in the Salona Formation was observed in samples from limestones which occur adjacent to metabentonite layers. Silica and magnesia associated with metabentonite layers may be formed by (1) divitrification of volcanic ash, (2) precipitation from sea water whose chemistry was influenced by the presence of volcanic materials, or (3) precipitation from mica- or magnesia-charged waters that were confined above or below impermeable metabentonite layers. Of the three possibilities, hypothesis (1) is favored by Whitcomb (1932a), Weaver (1953) and Grim (1954). Grim reports that volcanic ash generally contains an excess of silica and magnesia which, upon devitrification of the ash, would provide free silica and magnesia to adjacent beds. Weaver reports that large percentages of iron also are associated with metabentonite layers, but this relationship has not been observed by the writer.

One might ask, how a single layer of volcanic ash could provide enough free silica and magnesia to silicify or dolomitize limestones that occur several feet above and below. A partial answer to this question is provided by Weaver (1953) who concluded from studies of metabentonites in the Salona Formation that a layer of volcanic ash may only represent the climax of a volcanic episode which began somewhat earlier and ended somewhat later. Hence, silica and magnesia might be contributed in part to limestones adjacent to metabentonite layers by devitrification of dispersed volcanic ash.

In parts of the Coburn Formation, authigenic quartz crystals and other types of quartz occur in calcirudites and calcarenites that are not associated with obvious metabentonite layers. In these limestones, it is possible that the volcanic ashes have been reworked into the other sediments, as suggested by Rones (1955) from the study of other Middle Ordovician limestones in central Pennsylvania, or that silica was provided by sources (2) and (3), as described above.

Mode of Origin of Rhythmic Deposits

The rhythmic deposits of the Salona and Coburn Formations appear to constitute a single basic type. A rhythm commonly is marked at the base by an abrupt and sometimes irregular contact that is overlain by a relatively coarser-grained limestone which grades upward into finer-grained limestones, and these in turn into calcareous shale. The upward decrease in grain size generally is accompanied by an increase in the percentage of argillaceous material and lime mud, a decrease in the amount and size of sparry calcite cement, and a darkening of the color of the rock. In some rhythmic deposits, some of the component rock types are absent.

Rhythmic deposits are not apparent in the New Enterprise Member, but comprise the dominant percentage of the Roaring Spring, Milesburg and Coleville Members. A rhythmic deposit characteristic of the Roaring Spring Member commonly is less than six inches thick and contains calcarenite, calcilutite and calcareous shale in ascending order (Plate 12, Figures 1 and 2). In contrast the rhythms characteristic of the members of the Coburn Formation are generally less than 10 inches thick and contain bioskeletal calcirudites in addition to lithotypes observed in the rhythms of the Roaring Spring Member (Plate 11, Figures 1 and 2). In some parts of the rock sequence, the rhythmic deposits are poorly developed.

In hypothesizing a mode of origin of the rhythmic deposits, it appears to the writer that the following facts must be explained:

1. the hundreds of repetitions of a few basic rock types which are generally less than 10 inches thick in the Coburn Formation and less than six inches thick in the Roaring Spring Member of the Salona Formation;

2. the upward decrease in grain size;

3. the separate occurrences of the bulk of the fossil remains, pellets, lime mud and argillaceous material in bioskeletal calcirudites, calcarenites, calcilutites and calcareous shales, respectively;

4. the poor development of rhythms in some parts of the rock sequence.

That the rhythms of the Salona and Coburn Formations contain only a few basic rock types, and that the rock types are repeated at comparatively short, but fairly regular intervals, indicates that a limited number of events, or perhaps a single event, was repeated time after time during deposition of these sequences. If the rhythms formed as a result of step by step subsidence and sedimentary upbuilding, one would expect the sediments at the tops of the rhythms to be coarser and to reflect a greater current or wave activity than the sediments at the bottoms of the rhythms. The rhythms of the studied formations are just the reverse of this. In addition, it is difficult to visualize subsidence occurring at such small intervals for such a great number of times.

It seems more likely that the rhythmic deposits formed in shallow water where the sediments were churned up periodically by some agent. In such a case, the graded sequences would result from the orderly settling of suspended materials as the current strength subsided, and the initial sediment before churn-up might have been a relatively homogeneous mass that contained all of the textural components now seen in the graded deposits. The agents most likely to cause churn-up of sediments are storm waves and perhaps turbidity currents.

The formation of the rhythmic deposits would be difficult to explain if one assumed that the different rock types accumulated in adjacent micro-environments that were rapidly shifting back and forth on the sea floor. Instead of a regular alternation of rock types, one would expect to find a complex interlensing of rock types under these conditions. However, this pattern of deposition might account for the deposition of those parts of the rock sequence which have poorly developed rhythmic deposits.

MAJOR LITHOFACIES: THEIR DEPOSITIONAL ENVIRONMENTS AND HISTORY OF SEDIMENTATION

MAJOR LITHOFACIES AND THEIR POSSIBLE DEPOSITIONAL ENVIRONMENTS

The rocks of the Salona and Coburn Formations comprise three major lithofacies bodies which appear to have been deposited in different depositional environments. These lithofacies bodies correspond to (1) the New Enterprise Member of the Salona Formation, composed of black, variably argillaceous calcilutites, (2) the Roaring Spring Member of the Salona Formation, containing rhythmic deposits without bioskeletal layers, and (3) the Coburn Formation as a whole, composed of rhythmic deposits with bioskeletal layers. In the following discussion, the three major lithofacies bodies respectively are referred to as the black calcilutite facies, the non-bioskeletal rhythmic facies and the bioskeletal rhythmic facies. The general characteristics of the lithofacies and their possible depositional environments are summarized in Table 7. Two biofacies or faunal groups recognized in the Coburn Formation include the *Sowerbyella* biofacies and the *Dalmanella* biofacies. The comparative environmental significance of the two biofacies is unclear at the present time and therefore is not treated in the present discussion.

The black calcilutite facies, non-bioskeletal rhythmic facies and bioskeletal rhythmic facies all contain marine fossils and therefore

Table 7. *General lithologic and faunal characteristics, and speculative depositional environments of major facies of the Salona and Coburn Formations.*

Facies	Characteristics of Facies			Speculative Depositional Environments	
	General Lithologic and Faunal Characteristics	Bedding and Sedimentary Structures	Petrographic Characteristics		
Bioskeletal rhythms	Rhythmic deposits of bioskeletal calcirudites, calcarenites, calcilutites and calcareous shales. Fossils abundant and varied.	2- to 10-inch beds, some laminated and cross-laminated, others graded. Ripple-marked and lensing beds rare.	Calcirudites composed mostly of fossil grains cemented by megasparry calcite. Other lithotypes as below.	Marine	Shallow well-oxygenated banks with relatively strong current activity. Above wave base.
Non-bioskeletal rhythms	Rhythmic deposits of calcarenites, calcilutites and calcareous shales without bioskeletal layers. Fossils very sparse.	2- to 6-inch beds, some laminated and cross-laminated, few ripple marked or lensing.	Calcarenites composed mostly of carbonate pellet-grains cemented by microsparry calcite. Calcilutites as below.		Fairly shallow slopes of banks, near wave base with fair current activity, undesirable for organisms.
Black Calcilutite	Black calcilutites, sparsely fossiliferous.	6-inch to 1-foot beds. Structureless.	Calcilutites composed largely of argillaceous microcrystalline calcite lacking visible grains.		Relatively deeper water areas with very weak current activity.

were deposited in a marine environment. Within this broad environment, however, the lithofacies probably accumulated in quite different loci with respect to current activity, relative depth of water, and conditions necessary for the existence of organisms.

The bioskeletal rhythmic facies probably accumulated above wave base in comparatively shallow-water areas, possibly on banks or shoals, where the sediment was churned up periodically, the bottom was well oxygenated, and other conditions were favorable for the support of abundant and varied organisms.

In contrast to the bioskeletal rhythmic facies, the black calcilutite facies probably accumulated in areas of quiet water with weak or no bottom circulation. Conditions such as these may exist in shallow, protected areas or in relatively deeper water, below wave base.

The present lime mud accumulation in the lagoonal area on the leeward side of Andros Island in the Bahamas, as reported by Newell and Rigby (1957), is an example of deposition of lime mud in shallow, protected areas. In this region, lime mud is precipitating either biogenically or physico-chemically in less than three fathoms of water which is protected from current activity on the east by Andros Island, and on the west by the bank margin on which wave energy is dissipated. On the banks west of the lagoon, non-bioskeletal and bioskeletal lime sand are accumulating concurrently with the lime mud. The lime mud reaches a maximum of about 30 feet thick near the western shore of Andros Island and thins bankward and shoreward. Part of the westward extent of the lime mud area is attributed by Newell and Rigby (1957) to the westward transportation of lime mud by flood waters. The mass of lime mud in the lagoon extends for about 40 miles from west to east, about 50 to 75 miles from north to south, and is reported to be the largest area of lime mud accumulation in the world at the present time.

The black calcilutite facies of the Salona Formation also may have been deposited in a relatively protected area, but estimation of the depth of water is problematical. This facies thins slightly and is locally unconformable over the region of the Adirondack axis which may have acted as a partial, mostly submerged barrier in eastern central Pennsylvania during New Enterprise time. (Figure 14). At the same time, the shallow banks represented by the bioskeletal rhythmic facies might have formed a partial barrier toward the west, perhaps in the present location of western Pennsylvania or eastern Ohio. If these barriers were present, one would find a broad, fairly well protected basin between them in which the black calcilutites could accumulate and not be disturbed by bottom currents.

In central Pennsylvania, the black calcilutite facies is a time-rock body, about 100 feet thick, that extends for a least 100 miles from north to south, 50 miles from west to east and perhaps much farther beyond the area of the present study. It is composed of aphanitic, variously argillaceous limestones that lack sedimentary structures and observable grains, and does not contain interbeds of other lithotypes that might be attributed to deposition in shallow water. Inasmuch as this facies apparently was deposited over a very extensive area at the same time, and does not contain interbeds of shallow-water deposits which might be expected in extremely shallow water, it is suggested that the black calcilutite facies accumulated in comparatively deeper water than is presently found over the Bahama Banks, although perhaps still shallow in the absolute sense.

The non-bioskeletal rhythmic facies presumably accumulated in an environment intermediate between those of the black calcilutite facies and the bioskeletal rhythmic facies. The rocks which comprise this facies possibly were deposited near wave base in an area of fairly strong current activity, but perhaps deep enough that the bottom was not well oxygenated or where temperatures, salinities or other conditions were unsatisfactory for most organisms.

In summary, it appears most likely to the writer that the black calcilutite facies, the non-bioskeletal rhythmic facies and the bioskeletal rhythmic facies respectively were deposited in progressively shallower water, and probably accumulated in adjacent loci. The three facies apparently operated together as a transgressive sequence during Salona and the early part of Coburn time, and as a regressive sequence during later Coburn and earlier Antes time, as explained in the following pages.

HISTORY OF SEDIMENTATION

The depositional history of the Salona and Coburn Formations in central Pennsylvania, and of equivalent beds in southern and eastern Pennsylvania, as studied by Craig (1949) and Prouty (1959), is summarized in Figure 14. The line of cross-section represented in Figure 14 is shown on the index map on which the letters B, C and J designate the localities of Bellefonte, Chambersburg and Jacksonburg, respectively. The approximate limits of areas studied by Craig and Prouty are indicated along the cross-section in Figure 14A. The vertical scale of these diagrams is greatly exaggerated.

The correlations of the Salona and Coburn Formations with rock bodies in eastern Pennsylvania and western New Jersey, as reported by Prouty (1959), are illustrated in Figure 13. The lithologic and faunal characteristics of the rock bodies names in Figure 13 are mentioned briefly where applicable to the following discussion.

During Nealmont time, the seas gradually spread eastward into southwestern New Jersey, and the Nealmont and reported equivalent sediments overlapped most parts of the positive, upwarped, northeasterly-trending areas of the Adirondack axis and the Harrisburg barrier, whose positions are located approximately on Figure 14A. According to Craig (1949), the Adirondack axis passes through Path Valley, northwest of Chambersburg, and perhaps is a southerly extension of the Adirondack axis described by Kay (1937) from the Mohawk Valley of New York. The Harrisburg barrier, discussed at some length by Ulrich (1911), Willard (1939), Woodward (1957), Hobson (1958) and Prouty (1959), passes through the vicinity of Harrisburg and seems to parallel the Adirondack axis. The positions of these positive barriers in Nealmont time are hypothesized on the basis of major facies changes and local unconformities in the rocks overlying them.

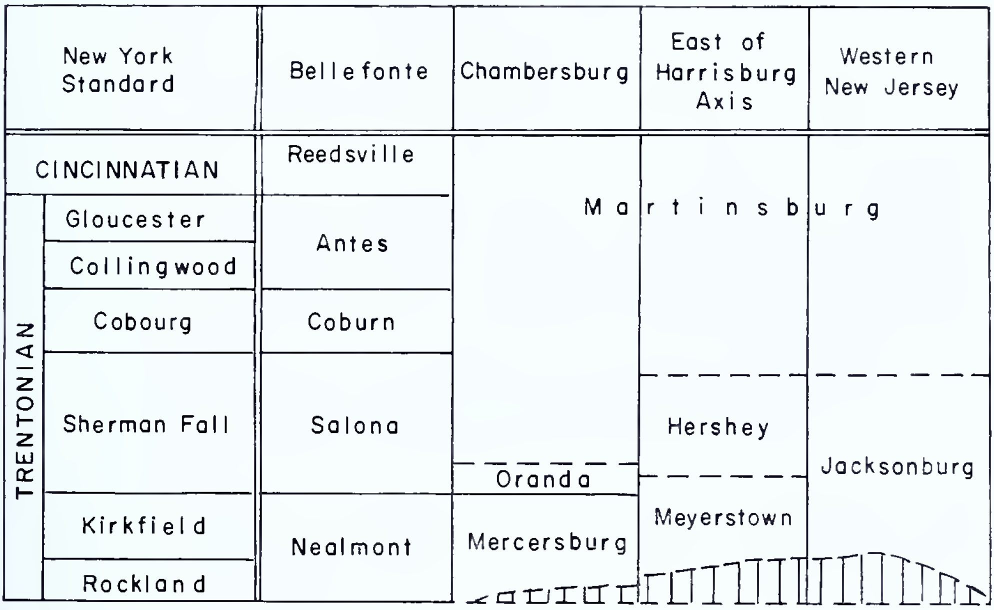

Figure 13. **Correlation of the Salona and Coburn Formations with rock bodies in eastern Central Pennsylvania**

At the end of Nealmont time, the Adirondack axis possibly was locally exposed to erosion along its extent. The local unconformity reported by Kay (1944) to separate the Nealmont Formation from the overlying New Enterprise Member in the vicinity of Antes Gap in Lycoming County might mark the approximate position of the northerly extension of the Adirondack axis in central Pennsylvania. If this were true, the reported unconformity would indicate that near Antes Gap the Adirondack axis may have been exposed or in very

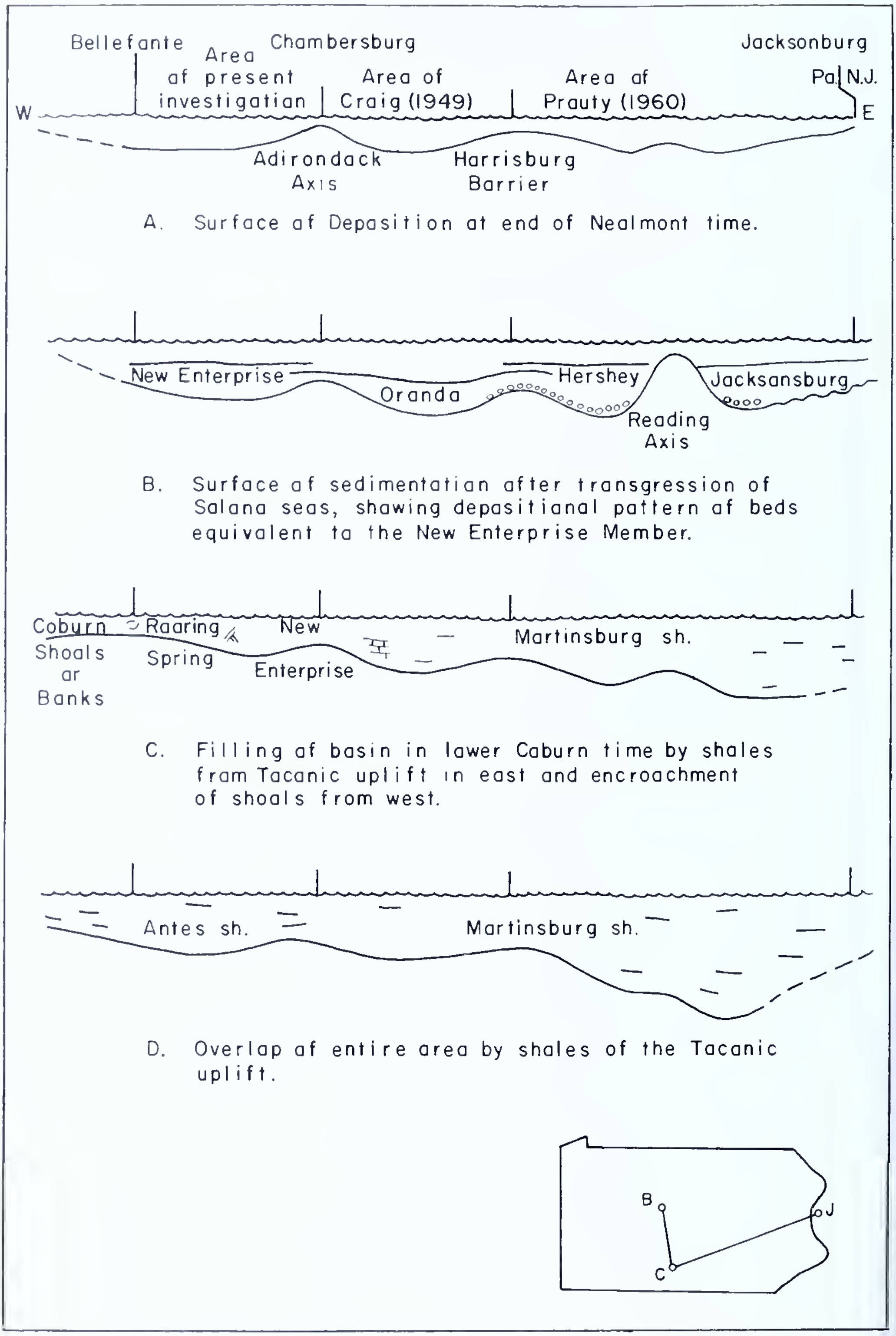
Bellefonte
Area of present investigation
Chambersburg
Area of Craig (1949)
Area of Prouty (1960)
Jacksonburg
Pa. N.J.
W
E
Adirondack Axis
Harrisburg Barrier
A. Surface of Deposition at end of Nealmont time.
New Enterprise
Oranda
Hershey
Jacksonsburg
Reading Axis
B. Surface of sedimentation after transgression of Salona seas, showing depositional pattern of beds equivalent to the New Enterprise Member.
Coburn Shoals or Banks
Roaring Spring
New Enterprise
Martinsburg sh.
C. Filling of basin in lower Coburn time by shales from Taconic uplift in east and encroachment of shoals from west.
Antes sh.
Martinsburg sh.
D. Overlap of entire area by shales of the Taconic uplift.
B
C
J

Figure 14. Paleogeography and depositional history of the Salona and Coburn Formations and equivalent beds in central and eastern Pennsylvania

shallow water at the end of Nealmont time. These higher parts along the axis possibly were more favorable loci for organisms, a hypothesis which would explain why the bioskeletal beds of the Rodman Member of the Nealmont Formation are present in the area of Antes Gap, but are nearly absent in Path Valley along the southerly extension of the axis.

In the early part of Salona time, the Adirondack axis and the Harrisburg barrier were largely submerged, perhaps in relatively deep water, and were overlapped by variously argillaceous sediments similar to those of the black calcilutite facies, as indicated in Figure 14B. At the same time, the initial stages of the Taconic deformation began to the east of the Jacksonburg area, supplying clays to the Appalachian trough. These clays spread westward into the Chambersburg region where, according to Craig (1949), their westward movement might have been inhibited by the relatively positive, but still submerged Adirondack axis. Craig reports that the sediments of the black calcilutite facies are markedly less argillaceous to the northwest of the axis than they are to the southwest.

Shortly after the black calcilutites began to accumulate over central Pennsylvania, the Reading axis, as reported by Hobson (1958) and Prouty (1959), was exposed above the surface of the sea and was actively eroding in eastern Pennsylvania. Erosion of this area provided the conglomeratic material which is found in that region at the base of the Hershey Limestone and locally in the Jacksonburg Limestone. According to Hobson and Prouty, these conglomerates, composed of fragments from Beekmantown-like dolomites, spread to the west of Harrisburg, indicating that the Harrisburg barrier was ineffective as a positive area at this time. Hobson suggests that the Jacksonburg Limestone was deposited in basins separated by positive areas, rather than in an interconnected basin.

Following the transgression of the seas and the submergence of parts of the Appalachian trough, as indicated by the overlap of the positive areas by calcilutites similar to those of the black calcilutite facies, the trough commenced to be filled in from both the east and west (Figure 14C). Detrital clays from the Taconic orogenic belt entered the Appalachian trough from the east. At the same time, the fossil banks on which the bioskeletal rhythmic facies was being deposited began to encroach into the trough from the west, either as the westernmost parts of the basin were uplifted slightly or as the banks built eastward in biostromal fashion. In this manner, the black calcilutite, non-bioskeletal rhythmic and bioskeletal rhythmic facies moved eastward toward the source area as a transgressive sequence, as shown in Figure 15.

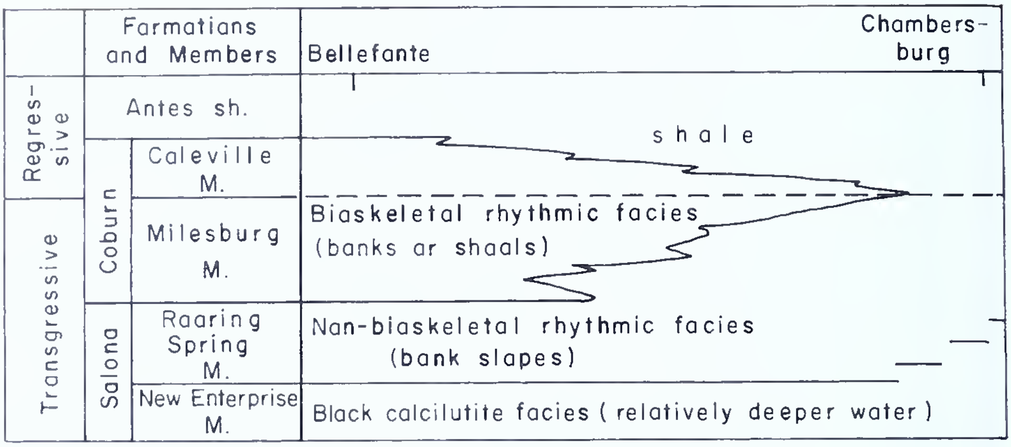

Figure 15. **Transgression and regression of major facies of Salona and Coburn Formations in central Pennsylvania**

The banks continued to move eastward until the middle of Coburn time when they extended almost to the Adirondack axis. Because the bioskeletal rhythmic facies does not extend to the east of the position of the Adirondack axis, Kay (1944) suggested that the axis was still positive at this time and inhibited the clays from the eastern source area from moving into the western part of the trough. As alternative hypotheses, it is possible that the rate of uplift of the eastern source area decreased in middle Coburn time, or that the westward moving clays were retarded by positive areas to the east of the Adirondack axis.

Toward the end of Coburn time, the clays from the Taconic deformation moved farther and farther westward until the entire region of central Pennsylvania was overlapped by the Martinsburg and Antes shales (see Figure 14D). The three facies, which formed the transgressive rock sequence during the eastward encroachment of the fossil banks, are not clearly identifiable in the regressive sequence, although their presence is suggested. The upper part of the Coburn Formation at Bellefonte and Salona contains recurrences of *Sowerbyella* bioskeletal calcirudites and of the trilobite *Cryptolithus tesselatus*, as well as shaly limestones at the base of the Antes shale, all of which may be the regressive equivalents of parts of the transgressive sequence. In view of the fact that the major facies of the transgressive rock sequence are not clearly distinguishable in the regressive sequence, it is suggested that regression was comparatively rapid (Figure 15), possibly reflecting an increase in the intensity of the Taconic disturbance and a corresponding decrease in the importance of the positive axes.

At various times during sedimentation of the Salona and Coburn Formations in central Pennsylvania, volcanic ashes were spread over the region from volcanoes to the east (Kay, 1935). The ashes, now altered to metabentonite, that were deposited in the black calcilutite facies apparently accumulated in quiet water and were not disturbed by bottom circulation, and thus are traceable throughout the region. With exception of metabentonite R, most of the ashes deposited in the bioskeletal and non-bioskeletal rhythmic facies were reworked locally and are not traceable to all sections of the region. Metabentonite R apparently was deposited at a time of comparative quiescence, and has served as a valuable datum plane in the present study.

The general history and pattern of sedimentation described above for Salona and Coburn time in central and eastern Pennsylvania might also apply to the type area of the Trenton Group in the Mohawk Valley of New York. The Adirondack axis, which may extend through Pennsylvania, was first postulated by Kay (1937) on the basis of stratigraphic studies in New York. Because of its presence, Kay divided the northern Appalachian region into the Magog and Champlain troughs. According to Kay (1944), the Coburn Formation of central Pennsylvania correlates with, and is similar in lithologic character to the Cobourg Formation of the Mohawk Valley. The Cobourg, like the Coburn, is a wedge-shaped rock body that thins from west to east and is limited in distribution to the western side of the Adirondack arch. It seems plausible that the Cobourg might have transgressed eastward into the Appalachian trough concurrently with the Coburn. The gross similarities between the two regions are striking.

SUMMARY AND CONCLUSIONS

1. The Salona and Coburn Formations each are subdivided into two new members on the basis of differences in lithologic and faunal characteristics.

The Salona Formation includes the New Enterprise Member and the overlying Roaring Spring Member. The New Enterprise Member is composed almost entirely of sparsely fossiliferous, black, somewhat argillaceous calcilutites, whereas the Roaring Spring Member is characterized by laminated and cross-laminated, fine-grained calcarenites that tend to occur in rhythmic alternations with calcilutites and calcareous shales.

The Coburn Formation includes the Milesburg and Coleville Members in ascending order. The Milesburg Member is characterized by

Sowerbyella and *Sowerbyella*-trilobite bioskeletal calcirudites, and the Coleville Member by *Dalmanella* and *Dalmanella*-crinoidal bioskeletal calcirudites. In both members, the calcirudites comprise less than 20 percent of the rock sequence and tend to occur in rhythmic deposits with calcarenites, calcilutites and calcareous shales.

2. Zones of contemporaneity are provided by metabentonite layers and fossil zones, some of which are newly recognized.

3. The Salona Formation, about 240 feet thick at Bellefonte, is a wedge-shaped rock body that thickens toward the southerly and easterly parts of central Pennsylvania as its upper beds replace the lower beds of the overlying Coburn Formation at gradually higher levels. The lower boundary of the Salona Formation parallels metabentonite layers over most of the region. The thickening of the Salona Formation occurs concurrently with a thinning of the Coburn Formation which diminishes by interfingering with incoming parts of the overlying Antes shale as well as of the underlying Salona Formation. Both formations disappear southeastward where they finally are replaced by the calcareous shales and argillaceous limestones of the lower part of the Martinsburg Formation. In the region of Chambersburg, the lower part of the Salona Formation below metabentonite No. 2 is replaced by the thin-bedded calcilutites of the Oranda Formation.

4. The New Enterprise Member is a 90- to 100-foot, blanket-like deposit with boundaries paralleling zones of contemporaneity over most of the region. In contrast, the Roaring Spring, Milesburg and Coleville Members thicken or thin toward the south and east in accordance with the above-described thickness variations of the parent formations. All members become increasingly argillaceous and less fossiliferous toward the southeast and east.

5. The six lithotypes recognized in the Salona and Coburn Formations include bioskeletal calcirudites, calcarenites, calcilutite, dolomitic limestones, calcareous shales and metabentonites. The bioskeletal calcirudites are subdivided into five sublithotypes on the basis of differences in fossil content. The calcarenites and calcilutites each are subdivided into two sublithotypes on the basis of the presence or absence of sedimentary structures and percentage of argillaceous material, repectively.

6. In thin sections the bioskeletal calcirudites consist dominantly of fossil remains cemented by megasparry calcite, and contain subordinate percentages of carbonate pellets, quartz crystals and fragments of lime mud as grains, as well as smaller percentages of lime mud as matrix. The calcarenites are composed principally of carbonate pellets which are cemented by microsparry calcite and are dis-

tributed in laminae and cross-laminae. Like the calcirudites, the calcarenites contain subordinate percentages of other mineral grains as well as of matrix. The calcilutites are largely composed of argillaceous lime mud with only a few obvious grains. The dolomitic limestones contain appreciable percentages of xenomorphic dolomite which are concentrated in laminae or bands.

7. The bioskeletal calcirudites and calcarenites probably formed in shallow water in areas of currents of sufficient strength to move the grains for at least short distances before their final deposition. In contrast, the calcilutites probably accumulated in areas with little current circulation, such as might be expected in relatively deep water below wave base or in shallow, protected areas. The dolomitic limestones either represent replacements of earlier limestones or concentrations of dolomite crystals that were transported by currents before deposition. The metabentonites seem to be products of altered volcanic ashes and the shales represent influxes of detrital material.

8. The rhythmic deposits of the Roaring Spring Member and of the Coburn Formation appear to constitute a single basic type. A rhythm commonly begins at the base with an abrupt and, in some cases, irregular contact. This contact is overlain by a relatively coarser limestone which grades upward into finer limestones, and these in turn into calcareous shale. The upward decrease in grain size is accompanied by an increase in the percentage of argillaceous material and lime mud and a darkening of the color of the rocks. The rhythmic deposits apparently formed in shallow water in which the sediments apparently were stirred up periodically, possibly by storm waves or turbidity currents.

9. The Salona and Coburn Formations are composed of three major lithofacies bodies, namely, the black calcilutite facies, the non-bioskeletal rhythmic facies and the bioskeletal rhythmic facies, corresponding respectively to the New Enterprise Member, the Roaring Spring Member, and to the Coburn Formation as a whole. In accordance with the general characteristics and time-space relationships of the facies, it seems plausible that the black calcilutite facies was deposited in relatively deep water where the sediments were little disturbed by bottom circulation. The non-bioskeletal and bioskeletal rhythmic facies, respectively, seem to reflect progressively shallower conditions and possibly were deposited on banks or shoals where wave or current action was comparatively strong. The three major lithofacies bodies apparently accumulated side by side and acted together as a transgressive sequence during Salona and early Coburn time and may have been a regressive sequence during later Coburn and early Antes time, although the regressive sequence is poorly developed.

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APPENDIX

MEASURED SECTIONS

ANTES GAP SECTION
(No. 1)

The Antes Gap section is located in the Williamsport, Pennsylvania, quadrangle about 7500 feet east of 77° 15′ longitude and about 3250 feet south of 41° 10′ latitude. The upper 50 feet of the Salona Limestone and the lower 85 feet of the Coburn Limestone are exposed continuously in a road cut immediately south of Antes Gap along the western side of State Highway 880. The cut is about one-third of a mile south of the intersection with State Highway 44. Beds strike about N. 80° E. and dip about 13° N.W.

Unit	*Lithologic description*	*Thickness*	
		Feet	
		Unit	*Total*
TRENTON GROUP			
COBURN FORMATION			
Coleville Member			
1.	Covered. Slope debris contains abundant slabs of abundantly argillaceous calcilutite and sparingly argillaceous calcilutite as well as a few fine-grained calcarenite layers and a single 1-inch lawer of crinoidal-*Dalmanella* bioskeletal calcirudite.	21½	38
2.	Calcilutite, argillaceous, very dark gray, in 4- to 6-inch, some 1-inch beds, with 1-inch interlayers of calcareous black shale.	5	16½
3.	Covered.	6½	11½
4.	Calcilutite, argillaceous, grayish black, in 4- to 6-inch beds, with interlayers of calcareous black shale (20%) up to 2 inches thick. Fine-grained calcarenite with a ½-inch stringer of crinoidal bioskeletal calcirudite in basal 1 foot.	4½	5
5.	Calcarenite, crinoidal bioskeletal, coarse-grained, grading upward into fine-grained calcarenite. Recrystallized nautiloid cephalopods numerous.	½	½
	Exposed thickness of Coleville Member.		38
Milesburg Member			
6.	Calcilutite, argillaceous, grayish black, in 2- to 4-inch, some 6-inch beds, alternating with calcareous shale in beds less than 2 inches thick. *Refinesquina* sp. rare.	6	47¼

7. Calcarenite, partly laminated, fine-grained, in 4- to 6-inch beds, with a 2-inch layer of *Sowerbyella* bioskeletal calcirudite which contains a few *Dalmanella* sp. and crinoid plates.	3	41¼
8. Covered.	5¾	38¼
9. Calcilutite (50%), argillaceous, grayish black, in 2- to 6-inch beds, in alternation with partly laminated, fine-grained calcarenite (40%) as well as with several calcareous shale interlayers, and a 2-inch bed of *Sowerbyella*-trilobite bioskeletal calcirudite at 1½-foot below top. Several ½-inch fossil layers on bedding surfaces, burrow-like structures on others.	17½	32½
10. Calcarenite, partly laminated, fine-grained, medium dark gray, in 4- to 6-inch beds, alternating with calcareous shale (25%) and several argillaceous calcilutite layers. Basal 6 feet with numerous ½-inch *Sowerbyella* bioskeletal calcirudite layers which contain numerous trilobite fragments and crinoid plates. Nautiloid cephalopods and burrow-like structures sparse.	15	15
Thickness of Milesburg Member		47¼
Exposed thickness of Coburn Formation		85¼

SALONA FORMATION

Roaring Spring Member

11. Calcilutite, argillaceous, very dark gray, in 4-inch beds, with several interbeds of partly laminated and cross-laminated, fine-grained calcarenite as well as with 1-inch interlayers of calcareous shale. *Sowerbyella* sp. and *Rafinesquina* sp. rare.	4½	49¾
12. Calcilutite (50%), argillaceous, grayish black, alternating with partly laminated and cross-laminated, fine-grained calcarenite (20%), both in 6-inch beds, as well as with calcareous black shale in beds less than 2 inches thick. *Sowerbyella* sp., *Rafinesquina* sp. and burrows rare.	7½	45¼
13. Calcilutite, abundantly argillaceous, black, in 1½-foot beds, alternating with argillaceous calcilutite (30%) in 8- to 10-inch beds.	5½	37¾
14. Calcilutite, abundantly argillaceous, black, *Rafinesquina* sp. and *Cryptolithus tesselatus* sparse.	5½	32¼
15. Metabentonite R, yellowish-weathered, 3 inches thick.	¼	26¾
16. Calcilutite, argillaceous, grayish black, in 4- to 6-inch beds, interbedded with calcareous black shale in beds less than 2 inches thick. *Rafinesquina obesa* and *Cryptolithus tesselatus* abundant in 1-inch lenses at 5 feet above base. *Dal-*		

	manella sp., *Sowerbyella* sp., trilobite fragments and crinoid plates sparse.	12	26½
17.	Calcarenite, fine-grained, partly laminated and cross-laminated, in 2- and 4-inch beds, with *Sowerbyella* sp., *Dalmanella* sp. and parts of crinoids and trilobites. Several metabentonite layers at 1, 2, and 5½ feet above base. Burrow-like structures abundant.	7½	14½
18.	Calcilutite, argillaceous, very dark gray, in 1-foot beds. *Sowerbyella* sp., *Dalmanella* sp., *Refinesquina* sp., trilobite parts and crinoid plates on bedding surfaces.	4	7
19.	Calcilutite, abundantly argillaceous, grayish black, in 1-foot beds. Fossils as in unit above.	3	3
	Exposed thickness of Roaring Spring Member		49¾
	Exposed thickness of Salona Formation		49¾

SALONA SECTION

(No. 2)

The type section of the Salona Formation is located in the Lock Haven, Pennsylvania, quadrangle, about 8,500 feet east of 77° 30′ longitude and about 2,000 feet north of 41° 05′ latitude. The Salona and Coburn Formations are partially exposed in a cut along the eastern side of railroad tracks leading northward from a quarry in the village of Salona toward Mill Hall. The base of the Salona Formation is exposed in the axis of a small drag fold at the northern end of the quarry. The beds strike N. 70° E. and dip 75° NW.

Unit	*Lithologic description*	*Thickness* *Feet* *Unit*	 *Total*
TRENTON GROUP			
ANTES SHALE			
	Covered.		
	Calcareous black shale, with several 6- to 10-inch interbeds of argillaceous limestone.	22	22
	Thickness of exposed Antes shale		22
COBURN FORMATION			
Coleville Member			
1.	Calcilutite, argillaceous, grayish black, in 6-inch beds with numerous ½- to 4-inch interlayers of *Dalmanella* and *Sowerbyella* bioskeletal calcirudite which are thickest in lower one-half of unit. *Cryptolithus tesselatus,* trilobites and *Prasopora* (?) sp. Mostly covered.	25	189¼

2. *Sowerbyella* and *Dalmanella* bioskeletal calcirudite with trilobite fragments, in 1-inch beds. Mostly covered.	9½	164¼
3. *Dalmanella* bioskeletal calcirudite (30%), in alternation with partly laminated, fine-grained calcarenite (10 to 20%) as well as with argillaceous calcilutite (20%) and with calcareous black shale (25 to 35%). Limestone beds, 4 to 6 inches thick are separated by shale beds, 1 to 6 inches thick. *Cryptolithus tesselatus* at 9 feet above base.	12	154¾
4. Shale, calcareous, black (60%), in beds up to 6 inches thick, alternating with limestone types as in above unit.	6	142¾
5. *Dalmanella* bioskeletal calcirudite (30 to 40%) in 6- to 10-inch beds, alternating with partly laminated and cross-laminated, fine-grained calcarenite (10 to 20%) as well as with argillaceous calcilutite, (20%). Interlayers of calcareous black shale (30 to 40%), up to 1 foot thick, separate the limestone layers.	36	136¾
6. Metabentonite, yellowish-weathered, 1½ inches thick.		
7. Limestone beds like those in unit 5, but with only 10% shale. Few *Sowerbyella* sp. and *Dalmenella* sp.	27	100¾
8. Calcarenite (50%), fine-grained, alternating with *Dalmanella* bioskeletal calcirudite (40%) and with very little calcareous shale. Limestone beds 8 inches to 1 foot thick. *Sowerbyella* sp. numerous; *Prasopora* (?) sp., bryozoans, *Rafinesquina* sp., gastropods and crinoid plates sparse.	23	73¾
9. Limestone beds as in unit 9, but with *Sowerbyella* bioskeletal calcirudite. Numerous *Dalmanella* sp.; few *Prasopora* (?) sp., gastropods and crinoid plates. Calcareous shale interlayers, 1 inch thick, increase in number upwards. Beds slightly undulose.	23	50¾
10. *Dalmanella* and *Sowerbyella* bioskeletal calcirudites (75%), in 8-inch to 1-foot beds, alternating with partly laminated and cross-laminated, fine-grained calcarenite. Few *Rafinesquina* sp., gastropods and trilobite fragments.	9	27¾
11. Calcarenite (40%), fine-grained, partly laminated and cross-laminated, alternating with calcareous black shale (30%) as well as with *Dalmanella* bioskeletal calcirudite (30%), all in 2- to 7-inch beds. Numerous crinoid plates; few *Prasopora* (?) sp., *Rafinesquina* sp. and trilobite fragments.	6¼	18¾
12. Calcilutite, argillaceous, grayish black, in 2- to 6-inch beds, alternating with calcareous black shale, in 1-inch beds, as well as with numerous 1-inch interlayers of crinoidal-*Dalmanella* bioskeletal calcirudite. Crinoidal bioskeletal		

layer, 3½ inches thick, at base. Abundant gastropods at 9 inches below top; few *Rafinesquina* sp.	12½	12½
Thickness of Coleville Member		189¼
Milesburg Member		
13. Calcarenite, fine-grained, medium dark gray, in alternation with black, argillaceous calcilutite, both in 1- to 2-inch nodular beds.	4½	131¾
14. Calcarenite, fine-grained, partly laminated and cross-laminated, medium dark gray, in alternation with black, argillaceous calcilutite, as well as with several 2-inch interlayers of *Sowerbyella*-trilobite bioskeletal calcirudite in middle of unit. Most beds are gently undulose and range from 3 inches to 1 foot thick.	28	127¼
Fault of unknown, but apparently small, displacement.		
15. Calcarenite, fine-grained, partly laminated and cross-laminated, in 4- to 6-inch beds, in alternation with numerous 1- to 4-inch calcareous shale interlayers as well as with several interlayers of black, argillaceous calcilutite, and with several 1- to 3-inch interlayers of *Sowerbyella*-trilobite bioskeletal calcirudite. Metabentonite (?), ½-inch thick, overlain by 4 inches of shade, at 7 feet above base. Upper 12 feet mostly covered.	29	99¼
16. Shale, calcareous, black, with several interlayers of black, argillaceous calcilutite and fine-grained calcarenite in upper 3 feet.	5	70¼
17. Metabentonite R, yellowish-weathered, 1 inch thick.		
18. Calcilutite (80%), argillaceous, black, in 4- to 6-inch beds, interlayered with fine-grained calcarenite (20%). *Sowerbyella* sp. numerous. Partly covered.	12	65¼
19. *Sowerbyella* bioskeletal calcirudite (50%), in 1- to 2-inch beds, alternating with 4- to 6-inch beds of fine-grained calcirudite.	7	53¼
20. Calcarenite, fine-grained, medium dark gray, in alternation with black, argillaceous calcilutite, both in 2- to 4-inch irregular beds.	9	46¼
21. Calcilutite (80%), argillaceous, black, in 2- to 6-inch beds, alternating with partly laminated, fine-grained calcarenite as well as with several 1-inch interlayers of *Sowerbyella* bioskeletal calcirudite in the lower part of the unit. Trilobite fragments, *Rafinesquina* sp. and *Prasopora* (?) sp. rare. Metabentonite (?), yellowish-weathered, 1 inch thick, overlain by 4 inches of calcareous shale, at 10 feet above base.	22	37¼
22. Metabentonite, yellowish-weathered, 1 inch thick, overlain by 3 inches of calcareous shale.	¼	15¼

23. Calcilutite, argillaceous, black, in 4- to 6-inch beds that contain several 1-inch stringers of *Sowerbyella* bioskeletal calcirudite. Several prominent 3- to 4-inch calcareous shale interlayers near base and top of unit.	6	15
24. Calcilutite, argillaceous, black, in 4- to 6-inch beds, alternating with fine-grained calcarenite as well as with numerous 3-inch beds of *Sowerbyella* bioskeletal calcirudite. *Parastrophia hemiplicata, Rafinesquina* sp. unid. *Prasopora* (?) sp. and trilobite fragments.	9	9
Thickness of Milesburg Member		131¾
Thickness of Coburn Formation		321

SALONA FORMATION

Roaring Spring Member

25. Calcilutite (80%), argillaceous, black, partly laminated, in 3- to 6-inch beds, alternating with partly laminated and cross-laminated, fine-grained calcarenite. Several 2-inch calcareous shale interlayers in basal 6 feet. *Sowerbyella* sp. rare.	21	103¾
26. Covered. Scattered exposed beds in lower 30 feet are partly laminated, very-fine-grained calcarenites, in 1- to 3-inch beds. *Sowerbyella* sp. numerous on some bedding surfaces.	70½	82¾
27. Calcilutite, argillaceous, black, in 2- to 3-inch beds, alternating with partly laminated and cross-laminated, fine-grained calcarenite and with abundantly argillaceous calcilutite. Uppermost 12-inch beds gradational from crinoidal calcarenite to argillaceous calcilutite at top. *Homalonotus trentonensis* (?), *Sowerbyella* sp., *Prasopora* (?) sp., nautiloid cephalopods and crinoid plates.	5	12¼
28. Metabentonite No. 5, yellowish-weathered, 2 to 3 inches thick.	¼	7¼
29. Calcarenite, very-fine-grained, abundantly laminated and cross-laminated, in 3- to 5-inch beds, alternating with black, abundantly argillaceous calcilutite. *Homalonotus trentonensis, Cryptolithus tesselatus, Rafinesquina* sp., *Dalmanella* sp. and recrystallized nautiloid cephalopods.	7	7
Thickness of Roaring Spring Member		103¾

New Enterprise Member

30. Calcilutite (60%), argillaceous, black, in 6- to 10-inch beds, alternating with abundantly argillaceous calcilutite. *Homalonotus trentonensis* in argillaceous layers, *Cryptolithus tesselatus, Dalmanella* sp., *Rafinesquina* sp. and recrystallized nautiloid cephalopods.	9	91

31. Calcilutite, argillaceous, black, in 6- to 10-inch beds, alternating with calcareous black shale (10%). Two 1½-inch laminated limestone layers at 6 and 12 feet above base. Basal 3 feet are medium crystalline limestone. *Homalonotus trentonensis* in argillaceous layers, *Cryptolithus tesselatus, Sowerbyella* sp. and recrystallized nautiloid cephalopods, all few in number.	15	82
32. Metabentonite No. 4, yellowish-weathered, 11 inches thick.	1	67
33. Calcilutite, argillaceous, black, in 6- to 8-inch, some 1-foot beds, alternating with abundantly argillaceous calcilutite layers that comprise as much as 40% of parts of the unit. *Isotelus* sp., *Rafinesquina* sp., *Sowerbyella* sp., *Dalmanella* sp., crinoid plates and trilobite parts scattered throughout unit; *Cryptolithus tesselatus* in lowermost 7 feet.	28	66
34. Metabentonite No. 3, yellowish-weathered, 3 inches thick, overlain by 3 inches of calcareous shale.	½	38
35. Calcilutite, argillaceous, black, in 6- to 10-inch beds, with several 6-inch interlayers of calcareous shale. Uppermost bed 12 inches thick. *Isotelus* sp. and *Rafinesquina* sp. in upper part of unit.	15	37½
36. Metabentonite No. 2, yellowish-weathered, 6 inches thick, overlain by 1 foot of calcareous shale with *Dalmanella* sp. and *Rafinesquina* sp.	1½	22½
37. Calcilutite, argillaceous, black, cherty in upper 2½ inches, in 8-inch beds. *Cryptolithus tesselatus* and *Rafinesquina* sp.	1½	21
38. Metabentonite No. 1, yellowish-weathered, 2½ inches thick.	¼	19½
39. Calcilutite, argillaceous, in 2- to 4-inch nodular beds, separated by ½-inch shale layers. Crinoidal calcarenite layer, 2 inches thick, at 3½ feet above base.	4½	19¼
40. Calcilutite, argillaceous, with 10 to 25% of coarser cleavage faces (crinoid plates), in 1½- to 3-inch nodular beds; numerous 1-inch calcareous shale interlayers. Bryozoan limestone bed at 2½ to 3 feet below top.	14½	14¾
41. Metabentonite No. 0, yellowish-weathered, 3 inches thick.	¼	¼
Thickness of New Enterprise Member		91
Thickness of Salona Formation		194¾

NEALMONT FORMATION

Rodman Member

Limestone, very finely crystalline, in 1- to 3-inch nodular beds.	17½	18½
Calcarenite, crinoidal.	1	1
Measured thickness of Rodman Member		18½

BELLEFONTE SECTION

(No. 3)

The Bellefonte section, here proposed as the reference section for the Coburn Formation in central Pennsylvania and as the type section for the Milesburg and Coleville Members of the Coburn, is located in the Bellefonte, Pennsylvania, quadrangle, about 9,750 feet west of 77° 45′ longtitude and about 1,250 feet north of 40° 55′ latitude. The exposure is located on the northern edge of the town of Bellefonte in a cut along the eastern side of Route 53 that leads to Milesburg. The base of the Salona limestone is located about 100 traverse feet north of a quarry cut in the Valentine limestone. Except for the basal part of the Milesburg Member, the Coburn is continuously exposed at this locality and the measured part totals about 292 feet thick. The New Enterprise Member of the Salona Formation is exposed entirely, but the Roaring Spring Member is almost completely covered. Beds strike about N. 65° E. and dip about 60° NW.

Unit	*Lithologic description*	*Thickness*	
		Feet	
		Unit	*Total*
TRENTON GROUP			
ANTES SHALE			
	Shale, calcareous, grayish black, brown weathering, with numerous *Triarthus* sp.	5	43
	Covered. Float contains calcareous shale and several calcarenite slabs with *Sowerbyella* sp.	15½	38
	Calcareous shale, grayish black, with interbeds of abundantly argillaceous calcilutite. Top of unit market by two 3-inch *Dalmanella* bioskeletal calcirudite layers with trilobite fragments, crinoid fragments and linguloid brachiopods. *Rafinesquina* sp. and *Cryptolithus tesselatus* sparse; ostracodes at 15 feet above base.	22½	22½
	Measured thickness of Antes shale		43
COBURN FORMATION			
Coleville Member			
1.	Crinoidal-*Dalmanella* bioskeletal calcirudite (85%), medium dark gray, in 3- to 6-inch irregular beds, with interbeds of calcarenite and calcareous black shale. Moderate numbers of *Cryptolithus tesselatus, Prasopora* (?) sp., bryozoans, gastropods and bryozoans; *Rafinesquina* sp. and *Sowerbyella* sp. rare.	22½	173½
2.	Shale (50%), calcareous, in beds up to 1 foot thick, in alternation with argillaceous calcilutite (25%), *Dalmanella* bioskeletal calcirudite (20%), in layers		

	less than 4 inches thick, as well as with laminated and cross-laminated, fine-grained calcarenite (5%). Many of the limestone beds are graded. Bioskeletal calcirudites are numerous in lower ½ of unit. Crinoid plates. *Prasopora* (?) sp., *Cryptolithus tesselatus* numerous; *Sowerbyella* sp., *Rafinesquina* sp., trilobite fragments and bryozoans rare.	27	151
3.	Shale (50%), calcareous, in beds up to 1 foot thick, alternating with argillaceous calcilutite (20%), in 4- to 8-inch beds, abundantly argillaceous calcilutite (10%) and fine-grained calcarenite (10%), *Sowerbyella* bioskeletal calcirudite (10%), in less than 2-inch beds, contain abundant *Cryptolithus tesselatus,* Rafinesquina sp., *Prasopora* (?) sp. and trilobite fragments. Pyrite abundant in some bioskeletal layers.	11½	124
4.	Shale (50%), calcareous, in layers up to 1 foot thick, alternating with argillaceous calcilutite (25%), abundantly argillaceous calcilutite (20%) as well as with 1- to 2-inch layers of crinoidal-*Dalmanella* bioskeletal calcirudite (5%). Beds commonly 4 to 8 inches thick. Crinoidal limestone layer, 6 inches thick, at 1½ feet below top. Trilobite fragments numerous; *Sowerbyella* sp. and *Prasopora* (?) sp. sparse. Bryozoans and ostracodes rare.	13	112½
5.	As unit above, but with 15% of partly laminated and cross-laminated, fine-grained calcarenite. Abundant pyrite in bioskeletal layers.	8	99½
6.	Shale, calcareous, black, with numerous 1-inch interlayers of *Dalmanella* bioskeletal calcirudite. Ostracodes numerous; trilobite fragments and bryozoans sparse.	1½	91½
7.	Calcilutite, argillaceous, dark gray, in 4- to 6-inch beds, with several interlayers of calcarenite in lower part, as well as with 1-inch bands of *Dalmanella* bioskeletal calcirudite at tops or bottoms of beds. Calcareous shale interlayers, up to 8 inches thick, comprise 40% of unit. Pyrite abundant in some bioskeletal layers. *Prasopora* (?) sp., crinoid plates, other bryozoans and trilobite fragments rare.	21	90
8.	Calcarenite (50%), partly laminated and cross-laminated, in 3- to 6-inch beds, with interlayers of argillaceous calcilutite (15%) and calcareous shale (25%) as well as with ½- to 3-inch beds of *Dalmanella* bioskeletal calcarenite with numerous bryozoans, trilobite fragments and few *Prasopora* (?) sp. Shale layers decrease in number and thickness toward top.	11	69

9. Metabentonite (?), yellowish-weathered, 1-inch thick, underlain by 5 inches of calcareous shale with numerous *Prasopora* (?) sp.	½	58
10. Calcarenite (40%), partly laminated and cross-laminated, dark gray, sparsely fossiliferous, in 4- to 6-inch beds, interlayered with crinoidal-*Dalmanella* bioskeletal calcirudite (30%) in 2- to 9-inch beds, as well as with ½- to 3-inch beds of calcareous shale and a few argillaceous calcilutite beds. *Prasopora* (?) sp. numerous; *Rafinesquina* sp., other bryozoans, and trilobite fragments rare.	13	57½
11. Metabentonite, yellowish-weathered, 2 inches thick, overlain by several inches of calcareous shale.	½	44½
12. *Dalmanella* bioskeletal calcirudite (50%), in 1- to 8-inch beds, alternating with numerous 4-inch to 1-foot beds of fine-grained calcarenite as well as with calcareous black shale (10%). *Sowerbyella* sp. and crinoid plates numerous; *Rafinesquina* sp., trilobite fragments and bryozoans rare. Beds are gently undulose.	10	44
13. Calcarenite (50%), partly laminated and cross-laminated, dark gray, in 4- to 10-inch beds, alternating with 1- to 7-inch interlayers of *Sowerbyella* and *Dalmanella* bioskeletal calcirudite (15-25%) as well as with 1- to 5-inch beds of calcareous black shale that comprise 40% of the upper one-half of the unit. Base marked by numerous 5-inch interlayers of calcareous shale. *Rafinesquina* sp., *Prasopora* (?) sp., other bryozoans and trilobite fragments sparse.	25	34
14. Calcilutite (50%), argillaceous, grayish black, in 4- to 6-inch beds, alternating with crinoidal bioskeletal calcirudite (10%) and several interbeds of calcarenite. Calcareous shale interlayers up to 6 inches thick comprise 30% of unit. Top of unit marked by 1-foot shale bed. *Dalmanella* sp., *Rafinesquina* sp., trilobite fragments and gastropods rare.	7½	9
15. Crinoidal bioskeletal calcirudite, in a single bed.	1½	1½
Thickness of Coleville Member		173½
Milesburg Member		
16. Calcilutite, argillaceous, dark gray, in 2- to 4-inch gently undulose beds, with 1- to 4-inch interbeds of *Sowerbyella*-trilobite bioskeletal calcirudite (10%). Calcareous shale interbeds (25%), up to 1½ inches thick, between each limestone layer. Upper 1½ feet is 60% shale. *Rafinesquina* sp. and *Dalmanella* sp. rare.	9	119
17. Calcilutite, argillaceous, dark gray, unfossiliferous, in 4-inch gently undulose beds, separated by ½-inch shale layers.	8¼	110

18. Calcarenite, partly laminated and cross-laminated, medium dark gray, in 4- to 6-inch irregular beds, alternating with argillaceous calcilutite (20%) as well as with *Sowerbyella*-trilobite bioskeletal calcirudite (10%). Calcareous shale, interlayers comprise 40% of lower 4 feet.	8	101¾
19. Metabentonite (?), yellowish-weathered, 1 inch thick.		
20. Calcarenite (60%), partly laminated and cross-laminated, medium dark gray, in 2- to 4-inch undulose beds with some 4- to 8-inch beds in lower 5 feet, with interlayers of argillaceous calcilutite as well as with several ½- to 3-inch *Sowerbyella*-trilobite bioskeletal calcirudite layers that are widely separated. Calcareous black shale interlayers up to 3 inches thick comprise 25% of unit. Black chert stringers, ½-inch thick, at 1 foot above base. *Prasopora* (?) sp. and nautiloid cephalopods rare. Crinoid stem segments on bedding surface 3 feet from top.	34½	93¾
21. Metabentonite, yellowish-weathered, in two 1-inch layers separated by 2½ inches of calcareous black shale.	¼	59¼
22. Calcarenite, partly laminated and cross-laminated, medium dark gray, in 2- to 6-inch undulose beds in lower five feet and 8- to 10-inch beds in upper 5 feet, alternating with 1- to 4-inch interlayers of *Sowerbyella* bioskeletal calcarenite (5%), as well as with 1-inch calcareous shale beds mostly in the lower 5 feet. *Rafinesquina* sp. numerous; *Prasopora* (?) sp. and other bryozoans sparse.	10	59
23. Metabentonite R, yellowish-weathered, 1½ inches thick, overlain by 3½ feet of calcareous shale and thin limestone interbeds. *Rafinesquina* sp. numerous.	3½	49
24. Calcilutite, argillaceous, dark gray, sparsely fossiliferous, in 3- to 4-inch beds, with 1- to 3-inch interlayers of calcareous black shale (25%). *Rafinesquina* sp. numerous; *Rafinesquina* sp. unid. on uppermost surface; crinoid plates and bryozoans sparse.	11½	45½
25. Calcarenite (60 to 70%), partly laminated and cross-laminated, medium dark gray, in 6- to 9-inch beds in upper 6 feet and in 1- to 3-inch beds in lower 6 feet, alternating with *Sowerbyella* bioskeletal calcirudite (15%), as well as with 1-inch calcareous shale interlayers that comprise 30% of lower 6 feet. Top marked by 6-inch bioskeletal layer. Crinoid plates and bryozoans numerous; *Dalmanella* sp., *Prasopora* (?) sp., *Rafinesquina* sp., trilobite fragments, gastropods and nautiloid cephalopods sparse; burrow-like structures rare.	12	34

26. Metabentonite, yellowish-weathered, 1 inch thick.		
27. Calcarenite, partly laminated, and cross-laminated, medium dark gray, in 4- to 8-inch beds, alternating with argillaceous calcilutite, very dark gray, as well as with *Sowerbyella* bioskeletal calcirudite (15%). Bioskeletal layers, 2 to 6 inches thick, lense out within outcrop. Fossils common on bedding surfaces. *Rafinesquina* sp. unid. at 2 feet above base; *Dalmanella* sp., *Prasopora* (?) sp. and bryozoans rare. Base of unit marked by 6-inch bioskeletal layer.	7½	22
28. Calcarenite, partly laminated and cross-laminated, medium dark gray, unfossiliferous, in 1-foot beds. *Dalmanella* sp. and bryozoans sparse on bedding surfaces.	5½	14½
29. Metabentonite, yellowish-weathered, 1 inch thick.		
30. Calcarenite, partly laminated and cross-laminated, medium dark gray, unfossiliferous, in 6-inch, with some 1-foot, undulose beds. Numerous 2- to 4-inch calcareous shale interlayers in basal 3 feet.	8	9
31. Shale, calcareous, black, unfossiliferous.	1	1
Thickness of measured part of Milesburg Member		119
Thickness of measured part of Coburn Formation		292½
32. (Covered interval. Float contains numerous 2- to 4-inch, partly laminated calcarenite layers with sparse number of *Sowerbyella* sp. on bedding surfaces. Salona and Coburn contact is concealed in this interval.)	120½	120½
Thickness of covered interval		120½
SALONA FORMATION		
Roaring Spring Member		
33. Calcilutite, argillaceous, very dark gray, in 4-inch beds, with a single 4-inch interlayer of calcarenite. Crinoid plates, brachiopods, and trilobite fragments rare. Black chert nodules, up to 2 inches in diameter, at 3 feet above base.	7¼	87¼
34. Covered interval.	78½	80
35. Calcilutite, argillaceous, dark gray to grayish black, in 2- to 6-inch beds with a buff-colored weathered crust up to 2 mm. thick, with several interlayers of partly laminated calcarenite.	1½	1½
Thickness of measured part of Roaring Spring Member		87¼
New Enterprise Member		
36. Calcilutite, structureless, dark gray to grayish black, in 2- to 6-inch beds that		

	weather with a buff-colored weathered crust up to 4 mm. thick, with several 2-inch interbeds of abundantly argillaceous calcilutite. Lowermost 3 feet are calcarenite; basal 1 foot is abundantly argillaceous calcilutite. *Homalonotus trentonensis* numerous in upper 7 feet; trilobite fragments, crinoid plates and brachiopod parts fairly numerous.	20½	91¼
37.	Metabentonite No. 4, yellowish-weathered, 8 inches thick.	¾	70¾
38.	Calcilutite, structureless, dark gray to grayish black, in 4- to 8-inch, some 10-inch beds that weather with a buff-colored crust up to 4 mm. thick, with several interlayers of abundantly argillaceous calcilutite. *Cryptolithus tesselatus* numerous in lower 10 feet; crinoid plates, trilobite fragments, *Isotelus* sp. and brachiopods are common.	30½	70
39.	Metabentonite No. 3, yellowish-weathered, 1¾ feet thick.	1¾	39½
40.	Calcilutite, argillaceous, structureless, dark gray to grayish black, in 3- to 8-inch beds that weather with a buff-colored weathered crust up to 4 mm. thick. *Cryptolithus tesselatus* common in lower 7 feet, *Isotelus* sp., trilobite fragments, crinoid plates, *Sowerbyella* sp. and brachiopods rare.	15¾	37¾
41.	Metabentonite No. 2, yellowish-weathered, 7 inches thick.	½	22
42.	Calcilutite, argillaceous, very dark gray, in 3- to 6-inch beds, with 2-inch siliceous limestone zone at top. Few crinoid plates and trilobite fragments.	1½	21½
43.	Metabentonite No. 1, yellowish-weathered, 5 inches thick.	½	20
44.	Calcilutite, argillaceous, very dark gray, in 2- to 6-inch beds, with two 2-inch bioskeletal calcarenite interlayers at 6½ and 10½ feet above base. Lower 6 feet contain from 10 to 30% of crinoid plates. Lower 6 inches is bioskeletal calcarenite in 1- to 3-inch beds. Brachiopods sparse.	19½	19½
45.	Metabentonite No. 0, yellowish-weathered, 1½ inches thick.		
	Thickness of New Enterprise Member		91¼
	Measured thickness of Salona Formation		178½

NEALMONT FORMATION

Rodman Member

Bioskeletal calcarenite, crinoidal, medium gray, in 1- to 3-inch, nodular-appearing beds which are separated by ½-inch shale layers.	10	10
Measured thickness of Rodman Member		10

WADDLE SECTION

(No. 4)

The Waddle section is located in the Bellefonte, Pennsylvania, quadrangle, about 4,500 feet west of 77° 55′ longitude and about 2,500 feet north of 40° 50′ latitude. The lower 142 feet of the Coburn Formation are well exposed about one-half mile north of Waddle in a cut along the northeastern side of a dirt road leading toward Bald Eagle Mountain. Most of the Salona Formation is covered, but the Rodman Member of the Nealmont Formation is well exposed so that the total thickness of the Salona Formation can be approximated. Beds strike about N. 63° E. and dip about 85° SE, and are overturned.

Unit	*Lithologic description*	*Thickness*	
		Feet	
		Unit	*Total*
TRENTON GROUP			
COBURN FORMATION			
Coleville Member			
1.	Crinoidal bioskeletal calcirudite, in 2- to 10-inch beds, interlayered with calcarenite (50%), in part laminated and cross-laminated.	5	5
	Exposed thickness of Coleville Member		5
Milesburg Member			
2.	Calcarenite, partly laminated and cross-laminated, fine-grained, medium dark gray, in 6- to 10-inch beds, alternating with *Sowerbyella* bioskeletal calcirudite (30-40%), as well as with calcareous shale interlayers. Bioskeletal layers up to 10 inches thick. Trilobite fragments common.	23	137
3.	Calcarenite, abundantly laminated and cross-laminated in lower one-half of unit, fine-grained, medium dark gray, in 4- to 6-inch, some 10-inch beds, with interlayers of *Sowerbyella*-trilobite bioskeletal calcirudite and calcareous black shale. Bioskeletal layers decrease in number upward. Metabentonite, 2 inches thick, at 7 feet above base.	36	114
4.	Metabentonite R, yellowish-weathered, 4 inches thick, overlain by 3½ feet of calcareous shale and 1- to 2-inch interbeds of argillaceous calcilutite.	4	78
5.	Calcarenite, partly laminated and cross-laminated, fine-grained, medium dark gray, alternating with argillaceous calcilutite as well as with 2- to 3-inch interlayers of calcareous shale. Beds are undulose and alternate from 2- to 4-inches thick to about 8 or 10 inches thick. Gastropods and brachiopods rare.	14½	74

6. Calcarenite, partly laminated and cross-laminated, very-fine-grained, medium dark gray to dark gray, in 2- to 4-inch beds with numerous ½- to 4-inch stringers, bands and beds of *Sowerbyella* bioskeletal calcirudite, as well as argillaceous calcilutite and layers of calcareous shale up to 3 inches thick. Argillaceous partings are common. Top marked by two 1-foot beds. Crinoid plates and burrows common; trilobites rare; *Rafinesquina* sp. unid. at 16½ feet above base.	41	59½
7. Calcarenite, partly laminated and cross-laminated, very-fine-grained, dark gray, commonly in 2- to 3-inch gently undulose beds, interlayered with argillaceous calcilutite, and several *Sowerbyella* bioskeletal stringers and bands less than 2 inches thick. Abundantly argillaceous calcilutite, 1 foot thick, at 8 feet above base. Top bed is 1 foot thick and undulose. *Parastrophia hemiplicata* rare.	18½	18½
Thickness of Milesburg Member		137
Exposed thickness of Coburn Formation		142
SALONA FORMATION		
8. Almost entirely covered. Scattered beds of laminated calcarenite are exposed in the upper part of the interval, and several argillaceous calcilutite layers are exposed in the lower part of the interval.	235	235
Thickness of covered interval		235
Approximate thickness of Salona Formation		235
NEALMONT FORMATION		
Rodman Member		
Crinoidal bioskeletal calcarenite in 2- to 3-inch nodular-appearing layers. In quarry.	10	10
Measured thickness of Rodman Member		10

MATTERNVILLE SECTION

(No. 5)

The Matternville section is located in the Bellefonte, Pennsylvania, quadrangle, about 9,500 feet east of 78° longitude, and about 2,500 feet south of 40° 50′ latitude. About 120 feet of the upper part of the Salona Formation and the lower 119 feet of the Coburn Formation are exposed in a quarry cut on the southern edge of the village of Matternville on the northeastern side of Pa. Rte. 550 leading south to Stormstown. Beds strike about N. 64° E. and dip about 87° SE.

Unit	*Lithologic description*	*Thickness* *Feet*	
		Unit	*Total*
	TRENTON GROUP		
	COBURN FORMATION		
	Milesburg Member		
1.	Calcarenite, fine-grained, abundantly laminated and cross-laminated, medium dark gray, in 3- to 7-inch beds, interlayered with *Sowerbyella*-trilobite bioskeletal calcirudite (25%) in beds up to 5 inches thick. Bioskeletal layers diminish upwards. Numerous calcareous shale interlayers. Black chert layer, about ½ inch thick, at 5 feet above base.	48½	119¼
2.	Metabentonite R, yellowish-weathered, 4 inches thick, overlain by 2 feet of calcareous shale.	2¼	70¾
3.	Calcarenite, fine-grained, abundantly laminated, and cross-laminated, medium dark gray, commonly in 2- to 3-inch beds. Topmost bed is 1 foot thick, interbeds of calcareous shale numerous, less than 1 inch thick.	12½	68½
4.	Calcarenite, abundantly laminated and cross-laminated, fine-grained, medium dark gray, in 1- to 6-inch beds, with numerous layers of argillaceous calcilutite and calcareous black shale, as well as with 1-inch bands of *Sowerbyella* bioskeletal calcirudite which are more numerous in upper part of unit. Crinoid plates numerous; trilobite fragments common in bioskeletal layers near top of unit.	56	56
	Exposed thickness of Milesburg Member		119¼
	Exposed thickness of Coburn Formation		119¼
5.	Covered interval. Probably a fault zone. Approximately 150 feet of section are absent, including the *Parastrophia hemiplicata* zone which occurs in this area at the base of the Coburn formation and a considerable thickness of the Roaring Spring Member of the Salona Formation.		
	SALONA FORMATION		
	Roaring Spring Member		
6.	Calcarenite, very-fine-grained, abundantly laminated and cross-laminated, with numerous interbeds of argillaceous calcilutite. Unfossiliferous.	32	32
	Exposed thickness of Roaring Spring Member		32
	New Enterprise Member		
7.	Calcilutite, argillaceous, grayish black, in 6-inch to 1-foot beds, with numerous interlayers of abundantly argillaceous		

	calcilutite. *Homalonotus trentonensis* common; trilobite fragments rare.	17	88
8.	Calcilutite, argillaceous, grayish black, in 2- to 4-inch beds. Partly covered.	1½	71
9.	Metabentonite, yellowish-weathered, 6 inches thick.	½	69½
10.	Calcilutite, abundantly argillaceous, black, in 1- to 3-inch beds with numerous interbeds of argillaceous calcilutite. Sparsely fossiliferous.	12	69
11.	Calcilutite, argillaceous, grayish black, in 2- to 7-inch beds, with several interlayers of abundantly argillaceous calcilutite.	25	57
12.	Calcilutite, abundantly argillaceous, black, in 1- to 3-inch beds with numerous interlayers of argillaceous calcilutite. Sparsely fossiliferous.	10	32
13.	Calcilutite, argillaceous, grayish black, in 2- to 6-inch, some 1-foot beds. Sparsely fossiliferous.	22	22
	Exposed thickness of New Enterprise Member		88
	Exposed thickness of Salona Formation		120

OAK HALL SECTION

(No. 6)

The Oak Hall section is located in the Bellefonte, Pennsylvania, quadrangle, about 7,500 feet east of 77° 50′ longitude and about 14,250 feet south of 40° 50′ latitude. The New Enterprise Member of the Salona Formation and the lower 102 feet of the Roaring Spring Member are completely exposed in the northern part of the Neidigh Brothers quarry about one-half mile north of the village of Oak Hall. The measured section is in that part of the quarry which is located west of the road between Oak Hall and Lemont. The beds at Oak Hall strike about N. 70° E. and dip about 55° NW.

Unit	*Lithologic description*	*Thickness* *Feet* *Unit*	*Thickness* *Feet* *Total*
TRENTON GROUP			
SALONA FORMATION			
Roaring Spring Member			
1.	Calcarenite (50%), fine-grained, in part laminated and cross-laminated, dark gray, with argillaceous calcilutite and calcareous shale. Limestone beds 2 to 4 inches thick with some 10-inch beds near base. *Dalmanella* sp., *Rafinesquina* sp., *Prasopora* (?) sp. and *Sowerbyella* sp. rare.	70	101¾
2.	Metabentonite, yellowish weathering, 3½ inches thick, overlain by 1 inch of calcareous shale.	¼	31¾

3.	Calcilutite (75%), argillaceous, grayish black, with few recrystallized nautiloid cephalopods and *Dalmanella* sp., interlayered with laminated and cross-laminated, fine-grained calcarenite. Beds 6 to 10 inches thick; uppermost bed 10 inches thick with ½-inch black chert stringers, up to 2 inches long, parallel to bedding.	6	31½
4.	Calcilutite, abundantly argillaceous, grayish black, in 4- to 6-inch beds with interlayers of laminated, fine-grained calcarenite (10%). Recrystallized nautiloid cephalopods rare.	6	25½
5.	Metabentonite, yellowish-weathered, 5 inches thick, with numerous pyrite nodules up to 1½ inches in diameter.	½	19½
6.	Calcilutite (80%), argillaceous, dark gray to grayish black, alternating with fine-grained calcarenite (15%), as well as with several interlayers of abundantly argillaceous calcilutite and ½-inch calcareous shale beds. Beds commonly 4 to 6 inches thick with several 10-inch beds near top. *Homalonotus trentonensis*, *Sowerbyella* sp., *Dalmanella* sp. and *Rafinesquina* sp.	19	19
	Thickness of exposed Roaring Spring Member		101¾
New Enterprise Member			
7.	Calcilutite, argillaceous, black, in 6-inch beds, interlayered with abundantly argillaceous calcilutite (10%). Sparsely fossiliferous with *Dalmanella* sp. and *Rafinesquina* sp., as well as *Homalonotus trentonensis* which first occurs at 6 feet above base and is especially abundant in argillaceous layers. Lower few feet of unit is medium crystalline limestone.	15	95¾
8.	Metabentonite No. 4, yellowish-weathered, 8½ inches thick, overlain by 7 inches of calcareous shale.	1¼	80¾
9.	Calcilutite, argillaceous, grayish black, in 5- to 7-inch beds, with interlayers of abundantly argillaceous calcilutite (10%). Scattered brachiopods, recrystallized nautiloid cephalopods and *Isotelus* sp. Abundant crinoid plates in abundantly argillaceous calcilutite layer at 5 feet above base.	11¼	79½
10.	Calcilutite, argillaceous, grayish black, in 1- to 3-inch beds, with ½-inch interlayers of calcareous shale, and several ½-inch stringers of crinoidal calcarenite. *Isotelus* sp., *Cryptolithus tesselatus* and *Rafinesquina* sp. rare.	3¼	68¼
11.	Calcilutite, argillaceous, grayish black, in 5- to 7-inch sparsely fossiliferous beds, with several 2-inch interlayers of calcareous shale in middle of unit. *Cryptolithus tesselatus*, *Isotelus* sp., *Rafinesquina* sp., gastropods and recrystallized nautiloid cephalopods sparse.	19¼	65

12. Metabentonite No. 3, yellowish-weathered, 6½ inches thick, overlain by 1½ inches of calcareous black shale.	¾	45¾
13. Calcilutite, argillaceous, grayish black, in 2- to 8-inch, some 15-inch beds, with interlayers of abundantly argillaceous calcilutite (10%) in 2- to 4-inch beds, as well as several 3-inch shale beds at 5 feet above base. Pyrite-filled gastropods at 6 feet above base. Brachiopods rare.	15½	45
14. Calcilutite, argillaceous in upper 3 feet, medium crystalline in lower 2½ feet, in 8- to 10-inch beds. Upper beds nodular. *Cryptolithus tesselatus* rare.	5½	29½
15. Metabentonite No. 2, yellowish-weathered, 6 inches thick, overlain by 2 inches of black calcareous shale with *Rafinesquina* sp. and linguloid brachiopods.	¾	24
16. Calcilutite, argillaceous, grayish black, in 6-inch beds. Cherty limestone in upper 1 inch.	2¼	23¼
17. Metabentonite No. 1, yellowish-weathered, 2 inches thick, overlain by 2½ inches of calcareous black shale and underlain by 4 inches of abundantly argillaceous calcilutite with *Cryptolithus tesselatus* and *Sowerbyella* sp.	¾	21
18. Calcilutite, argillaceous, grayish black, with ½-inch interlayers of calcareous shale in upper and lower 5 feet. Beds commonly 6 inches to 1 foot thick, but alternate with 2- to 4-inch nodular beds (30%) which are spaced 2 to 3 feet apart. Thick beds with ½- to 2-inch fossil stringers which contain brachiopods, *Prasopora* (?) sp. and bryozoans.	15½	20¼
19. Metabentonite No. 0, yellowish-weathered, 2 inches thick, overlain by 1½ inches of calcareous black shale.	¼	4¾
20. Calcilutite, argillaceous, grayish black, in a 1-foot bed.	1	4½
21. Calcilutite, argillaceous, grayish black, in 2- to 4-inch nodular beds, with ½-inch calcareous shale interlayers between each bed. *Cryptolithus tesselatus*, *Sowerbyella* sp., *Leptaena* sp. and *Dalmanella* sp. at 1 foot below top. Crinoid plates numerous in lower 2 feet.	3½	3½
Thickness of New Enterprise Member		95¾
Thickness of exposed Salona Formation		197½

NEALMONT FORMATION

Rodman Member

Limestone, in part crinoidal calcarenite, medium- to coarsely-crystalline, medium dark gray, in 1- to 2-inch beds, with interlayers of calcareous shale. Boundary between Nealmont and Salona Formations placed at top of uppermost crinoidal calcarenite layers.	4	4
Measured part of Rodman Member		4

BOALSBURG SECTION

(No. 7)

The Boalsburg section is located in the Bellefonte, Pennsylvania, quadrangle, about 14,500 feet north of 40° 45′ latitude and about 500 feet west of 77° 45′ longitude. The upper part of the New Enterprise Member and the lower part of the Roaring Spring Member of the Salona Formation are partially exposed in a road cut along both sides of Route 45 about 2½ miles northeast of Boalsburg. This exposure is correlated with other exposures on the basis of *Homalonotus trentonensis* which occurs near the base. Beds strike about N. 67° E. and dip about 33° SE.

Unit	*Lithologic description*	*Thickness*	
		Feet	
		Unit	*Total*
TRENTON GROUP			
SALONA FORMATION			
Roaring Spring Member			
1.	Calcarenite, abundantly laminated and cross-laminated, fine-grained, in 8-inch to 1-foot beds, with interlayers of abundantly argillaceous calcilutite. Partly covered.	4	120½
2.	Calcarenite, laminated and cross-laminated in part, fine-grained, in beds 4 to 6 inches thick, with 2-inch interlayers of calcareous shale in lower part, becoming partings in upper part. Base marked by abundantly argillaceous calcilutite, 1 foot thick. *Sowerbyella* sp. and *Dalmanella* sp. sparse.	22	116½
3.	Calcilutite, argillaceous, black, in 4- to 6-inch, some 8-inch beds, with numerous interlayers of faintly laminated, fine-grained calcarenite. Shaly partings between each limestone layer. Several 1-inch interlayers of coarser calcarenite at 1, 10 and 24 feet above base. *Sowerbyella* sp. common on some bedding surfaces; *Dalmanella* sp., bryozoans, trilobite fragments and other brachiopods rare; burrows common. This unit is exposed in part on both sides of the highway.	70	94½
4.	Calcilutite, argillaceous, in 1- to 3-inch beds, with numerous interlayers of partly laminated and cross-laminated, fine-grained calcarenite. Shaly partings separate each limestone layer. *Sowerbyella* sp. common on bedding surfaces in upper part; *Dalmanella* sp. rare. *Isotelus* sp. and bryozoans rare in lower part.	24½	24½
	Exposed thickness of Roaring Spring Member		120½

New Enterprise Member			
5.	Calcilutite, argillaceous, black, in 1-foot beds, *Homalonotus trentonensis* in lower foot; *Dalmanella* sp. and crinoid plates rare; burrows at 1 foot above base. Mostly concealed.	5½	20½
6.	Calcilutite, argillaceous, black, in 4- to 6-inch beds, with several interlayers of abundantly argillaceous calcilutite in lower part. *Cryptolithus tesselatus* near top; *Dalmanella* sp., *Sowerbyella* sp. and crinoid plates rare. Mostly concealed.	15	15
	Exposed thickness of New Enterprise Member		20½
	Exposed thickness of Salona Formation		141

OLD FORT SECTION

(No. 8)

The Old Fort section is located in the Centre Hall, Pennsylvania, quadrangle, about 6,000 feet east of 77° 40′ longitude and about 6,000 feet south of 40° 50′ latitude. About 309 feet of the lower part of the Coburn Formation and about 274 feet of scattered exposure in the upper part of the Salona Formation are exposed about 2 miles southeast of the traffic light at Old Fort in a cut along the southwestern side of Route 53. The cut is immediately south of the village of Centre Hall. Beds strike N. 53° E. and dip about 45° SE.

Unit	*Lithologic description*	*Thickness*	
		Feet	
		Unit	*Total*
TRENTON GROUP			
COBURN FORMATION			
Coleville Member			
1.	*Dalmanella* bioskeletal calcirudite (50%), in 1- to 5-inch beds, alternating with argillaceous calcilutite and calcarenite in 4- to 6-inch beds. *Isotelus* sp., trilobite fragments and brachiopods common; *Prasopora* (?) sp. and gastropods in uppermost bed and at 3 feet above base.	16	152
2.	Calcilutite, argillaceous, grayish black, in 2- to 6-inch beds with interlayers of *Dalmanella* bioskeletal calcirudite (5%) as well as abundantly argillaceous calcilutite. Brachiopods and trilobite fragments common.	10¼	136
3.	*Dalmanella* bioskeletal calcirudite (60-70%), in 1- to 6-inch beds, in alternation with 3- to 6-inch layers of calcarenite. *Sowerbyella* sp. numerous; *Isotelus* sp. at 1½ feet above base.	15	125¾

4. *Dalmanella*-crinoidal bioskeletal calcirudite and calcarenite (50%), in 2- to 6-inch, some 10-inch beds, alternating with argillaceous calcilutite as well as with ½- to 2-inch interlayers of calcareous shale which are more abundant in upper 6 feet. Lower 19 feet almost entirely bioskeletal calcirudite. Channel surfaces common below bioskeletal beds. *Sowerbyella* sp. and *Isotelus* species common; *gastropods* in lower 19 feet.	53½	110¾
5. Calcarenite, partly laminated and cross-laminated, fine-grained, medium dark gray, in 4- to 6-inch beds, with several interlayers of *Dalmanella* bioskeletal calcirudite. *Sowerbyella* sp. numerous; *Isotelus* sp. at 1 foot below top. Numerous shale interlayers.	5½	57¼
6. Metabentonite, yellowish-weathered, 6 inches thick.	½	51¾
7. Calcilutite, argillaceous, dark gray, in 4- to 6-inch beds, with numerous interlayers of crinoidal bioskeletal calcirudite, as well as ½- to 2-inch interlayers of calcareous shale. Several abundantly argillaceous calcilutite interlayers at 10 feet above base. Dolomitic bands scattered throughout unit. Metabentonite, 2 inches thick, at 2 feet below top. *Prasopora* (?) sp. at 6 feet below top.	31¼	51¼
8. Calcarenite, partly laminated and cross-laminated, fine-grained, medium dark gray, in 4- to 10-inch beds, with argillaceous calcilutite in upper part of unit. Numerous dolomitic bands. *Dalmanella* sp. and burrows rare.	9¼	20
9. Calcarenite, abundantly laminated and cross-laminated, medium dark gray, in 4- to 6-inch beds, with abundant interlayers of crinoidal bioskeletal calcirudite that contain numerous trilobite fragments in lower part. Many beds are graded.	10¾	10¾
Exposed thickness of Coleville Member		152
Milesburg Member		
10. Calcarenite, abundantly laminated and cross-laminated, medium dark gray, in 4- to 6-inch beds, with numerous interbeds of *Sowerbyella*-trilobite bioskeletal calcirudite.	7	157¼
11. Calcilutite, argillaceous, grayish black, in 4- to 6-inch beds, with several *Sowerbyella* bioskeletal calcirudites near base. Burrows common.	9¼	150¼
12. Calcarenite, partly laminated and cross-laminated, fine-grained, medium dark gray, in 4- to 6-inch gently undulose beds, with 3- to 4-inch interlayers of shale in lower 6 feet. Brachiopods sparse. Burrows common.	22½	140¾

13.	Metabentonite, yellowish-weathered, 2 inches thick, overlain by 3 inches of calcareous black shale.	½	118¼
14.	Calcarenite, partly laminated, fine-grained, medium dark gray, in 2- to 4-inch gently undulose beds, many of which are graded. Top marked by 1-foot bed grading from 6-inch layer of *Sowerbyella*-trilobite bioskeletal calcirudite into argillaceous calcilutite at top.	8½	117¾
15.	Calcilutite, abundantly argillaceous, black, with several interlayers of limestone that contain *Sowerbyella*-trilobite calcirudite bands up to 2 inches thick.	4¼	109¼
16.	Metabentonite R, yellowish-weathered, 1 inch thick, overlain by 1 foot of calcareous black shale.	1	105
17.	Calcilutite, argillaceous, dark gray to grayish black, in 4- to 6-inch beds with several 1-foot beds in upper 4 feet. Several interbeds of calcarenite, abundantly argillaceous calcilutite and calcareous shale.	10	104
18.	Calcarenite, structureless, fine-grained, medium dark gray, in 4- to 10-inch beds, with several interlayers of *Sowerbyella* bioskeletal calcirudite in basal 1 foot. *Dalmanella* sp. and *Rafinesquina* sp. rare.	6¾	94
19.	Metabentonite, yellowish-weathered, 1 inch thick, overlain by 5 inches of calcareous black shale.	½	87¼
20.	Calcarenite, structureless, fine-grained, medium dark gray, in 4- to 6-inch beds. Burrow-like structures sparse.	12¾	86¾
21.	Calcilutite, argillaceous, grayish black, in 4- to 6-inch beds, with numerous 1- to 2-inch bands and stringers of *Sowerbyella* bioskeletal calcirudite, as well as interlayers of calcarenite, abundantly argillaceous calcilutite and calcareous black shale. Burrows numerous; *Rafinesquina* sp. unid. at 4 feet above base. *Parastrophia hemiplicata* sparse.	36	74
22.	Calcilutite, argillaceous, dark gray, in 6- to 9-inch beds, with numerous interlayers of partly laminated and cross-laminated calcarenite, as well as with several 1- to 2-inch bands and stringers of *Sowerbyella* bioskeletal calcirudite. Top bed 15 inches thick. *Dalmanella* sp. sparse; burrow-like structures rare.	16	38
23.	Metabentonite, yellowish-weathered, 1½ inches thick, overlain by 5 inches of calcareous shale and thin interbeds of limestone.	½	22
24.	Calcilutite, argillaceous, in part laminated, grayish black, in 4- to 9-inch beds, with numerous interlayers of partly laminated and cross-laminated calcarenite, as well as several ½-inch bands and stringers of *Sowerbyella* bioskeletal calcirudite. Interlayers of abundantly argillaceous calcilutite at 10 to 15 feet above base. Metabentonite, 1½		

	inches thick, at 10 feet above base. *Sowerbyella* sp. and *Dalmanella* sp. numerous on some bedding surfaces; burrows rare.	21½	21½
	Thickness of Milesburg Member		157¼
	Exposed thickness of Coburn Formation		309¼
SALONA FORMATION			
Roaring Spring Member			
25.	Calcilutite, argillaceous, grayish black, in 3- to 5-inch beds, with interlayers of partly laminated and cross-laminated calcarenite. Mostly covered.	32½	32½
	Exposed thickness of Roaring Spring Member		32½
26.	Covered. Several beds of argillaceous calcilutite and calcarenite exposed.	274	274
	Thickness of covered interval		274
	Approximate thickness of Salona Formation		306½
NEALMONT FORMATION			
Rodman Member			
	Crinoidal bioskeletal calcarenites in 2- to 3-inch nodular-appearing beds.	7	7
	Measured thickness of Rodman Member		7

SPRING MILLS SECTION

(No. 9)

The Spring Mills section is located in the Centre Hall, Pennsylvania, quadrangle, about 3,000 feet east of 77° 35′ longitude and about 8,250 feet north of 40° 45′ latitude. The Salona and Coburn Formations are exposed for about 285 feet in a well-weathered cut immediately north of Spring Mills along both sides of Route 45. The section descends stratigraphically northward along a small southward flowing stream. From an average of four readings, beds strike N. 64° E. and dip 36° SE.

Unit	*Lithologic description*	*Thickness* *Feet*	
		Unit	*Total*
TRENTON GROUP			
COBURN FORMATION			
Milesburg Member			
Covered.			
1.	*Sowerbyella* bioskeletal calcirudite (50%), medium dark gray, in 2- to 6-inch beds, in alternation with fine-grained calcarenite (30%) and calcareous shale (20%). Trilobite fragments numerous. Unit partly covered.	8½	38½

2.	Shale, calcareous, black, with several 1- to 3-inch interbeds of argillaceous calcilutite in upper 4 feet. Brachiopods sparse.	6	30
3.	Metabentonite R, yellowish-weathered, 4 to 5 inches thick.	½	24
4.	Calcilutite, argillaceous, in part laminated, dark gray, in 3- to 5-inch beds, in alternation with black calcareous shale in layers up to 1 inch thick, as well as with numerous ½- to 2-inch layers of *Sowerbyella* bioskeletal calcirudite. Shales increase in upper 8 feet. *Sowerbyella* sp., brachiopods and burrow-like structures common.	20	23½
5.	Metabentonite, yellowish-weathered, 3 inches thick, overlain by 3 inches of calcareous black shale.	½	3½
6.	*Sowerbyella* bioskeletal calcirudite, medium dark gray, in 1- to 3-inch beds which alternate with 4- to 6-inch beds of fine-grained calcarenite. Beds undulose with 3 to 4 inches of relief. Burrow-like structures numerous.	3	3
	Exposed thickness of Milesburg Member		38½
	Exposed thickness of Coburn Formation		38½

SALONA FORMATION

Roaring Spring Member

7.	Calcarenite, partly laminated and cross-laminated, fine-grained, medium dark gray to dark gray, in 2- to 3-inch undulose beds, alternating with grayish black argillaceous calcilutite as well as with ½-inch interlayers of calcareous shale which separate each limestone bed. Burrows numerous; *Sowerbyella* sp. moderate in number on bedding surfaces; nautiloid cephalopods and *Prasopora* (?) sp. rare; *Cryptolithus tesselatus* at 5 feet to 7 feet above base.	15	130¼
8.	Calcarenite and argillaceous calcilutite as above but with numerous 2- to 4-inch interlayers of calcareous shale. *Sowerbyella* sp. rare. Metabentonite (?), ½-inch thick, at base.	6	115¼
9.	Calcilutite, argillaceous, in part laminated, dark gray, in 3- to 7-inch beds in lower one-half of unit and in 2- to 4-inch beds in upper one-half of unit, with ½- to 2-inch interlayers of calcareous black shale. Metabentonite, 3 inches thick, at 10 feet above base. *Rafinesquina* sp. unid. rare at 7 feet above base; brachiopods and crinoid plates numerous on some bedding surfaces; burrows rare. Several 6-inch shale interlayers at 13 to 16 feet above base.	23¾	109¼
10.	Calcarenite, partly laminated and cross-laminated, medium dark gray, in 2- to 7-inch beds with some 1-foot beds near base, with numerous ½- to 1-inch string-		

	ers of *Sowerbyella* bioskeletal calcirudite. Numerous 1- to 4-inch yellowish weathering dolomitic limestone in lower 6 feet. Bioskeletal layers contain numerous gastropods and few *Dalmanella* sp. and recrystallized nautiloid cephalopods. *Parastrophia hemiplicata* in upper two feet of unit. *Sowerbyella* sp. and crinoid plates numerous on bedding surfaces. Metabentonite, 1 inch thick, at 6 feet above base. This unit is regarded as a tongue of the Coburn Formation in the Roaring Spring Member.	10¼	85½
11.	Calcarenite, mostly laminated and cross-laminated, fine-grained, medium dark gray, in 4- to 6-inch, some 10-inch beds, alternating with 1-inch layers of calcareous shale. Beds gently undulose near top. *Sowerbyella* sp. and crinoid plates numerous on bedding surfaces; *Prasopora* (?) sp. and recrystallized nautiloid cephalopods at 1 foot below top.	9	75¼
12.	Shale, calcareous, black with several 1-inch interlayers of argillaceous calcilutite. Metabentonite, ½-inch thick, at 1 foot above base.	1	66¼
13.	Calcarenite, very-fine-grained, abundantly laminated and cross-laminated, dark gray, alternating with argillaceous calcilutite (35%), as well as with 1-foot interlayers of calcareous black shale which occur at about 5-foot to 8-foot intervals. Limestone beds 2 to 4 inches thick. Laminae most abundant near top where some are pyritic. Metabentonites (?), ½-inch thick, at 19 feet and 23 feet above base. Limestone layers with *Sowerbyella* sp., *Dalmanella* sp., *Prasopora* (?) sp.; *Rafinesquina* sp. unid. at 19 feet and 23 feet above base; *Leptaena* sp. rare in some of shale layers.	28	65¼
14.	Covered.	8	37¼
15.	Metabentonite, yellowish-weathered 2½ inches thick.	¼	29¼
16.	Mostly covered. Several exposed layers of fine-grained calcarenite, medium dark gray, in 3- to 5-inch beds.	22	29
17.	Calcarenite, very-fine-grained, medium dark gray to dark gray, in 3- to 5-inch beds. Partly covered.	7	7
	Exposed thickness of Roaring Spring Member		130¼
18.	Covered. Interval includes contact between Roaring Spring Member and underlying New Enterprise Member of Salona Formation.	34	34
	Thickness of covered interval		34
New Enterprise Member			
19.	Calcilutite, abundantly argillaceous, dark gray to grayish black, in 8-inch		

	to 1½-foot beds, with 4- to 8-inch interlayers of structureless, argillaceous calcilutite (25%). *Homalonotus trentonensis* occurs from 1 foot above base to top of unit; brachiopods and trilobite fragments rare.	13½	81½
20.	Metabentonite No. 4, yellowish-weathered, 3 inches thick.	¼	68
21.	Calcilutite, argillaceous, dark gray to grayish black, in 4-inch to 1½-foot beds.	11	67¾
22.	Calcilutite, abundantly argillaceous, dark gray to grayish black, in 6-inch to 2-foot beds.	12	56¾
23.	Covered.	5	44¾
24.	Calcilutite, argillaceous, dark gray to grayish black, in 3- to 5-inch beds with a 10-inch bed at base. Brachiopods and trilobite fragments rare.	5	39¾
25.	Metabentonite No. 3, yellowish-weathered, 6 inches thick, overlain by several inches of black calcareous shale.	½	34¾
26.	Calcilutite, argillaceous, dark gray to grayish black, in 6-inch to 1½-foot beds, with interlayers of abundantly argillaceous calcilutite (30%). *Cryptolithus tesselatus* and recrystallized nautiloid cephalopods common; *Isotelus* sp. and *Rafinesquina* sp. common in upper part of unit.	16½	34¼
27.	Metabentonite No. 2, yellowish-weathered, 6 inches thick.	½	17¾
28.	Calcilutite, argillaceous, dark gray, in 4-inch to 1-foot beds, with 2-inch band of black cherty limestone at top.	2	17
29.	Metabentonite No. 1, yellowish-weathered, 2 inches thick.	¼	15¼
30.	Calcilutite, argillaceous, dark gray to grayish black, in 4- to 10-inch beds. *Rafinesquina* sp. common at 2 feet above base; brachiopods rare. Mostly covered.	7	15
31.	Covered.	7	8
32.	Metabentonite No. 0, yellowish-weathered, 1 inch thick.		
33.	Calcilutite, argillaceous, dark gray, with 10% of coarser sparry calcite cleavage faces. Transitional zone.	1	1
	Exposed thickness of New Enterprise Member		81½
	Thickness of Salona Formation		245½

NEALMONT FORMATION

Rodman Member

Calcilutite, argillaceous, with 25% of crinoid plates, alternating with crinoidal bioskeletal calcarenites, in 2- to 3-inch nodular-appearing beds.	7	7
Measured thickness of Rodman Member		7

COBURN SECTION

(No. 10)

The type section of the Coburn Formation is located in the Millheim, Pennsylvania, quadrangle, about 9,000 feet east of 77° 30′ longitude and about 10,500 feet north of 40° 50′ latitude. The lower part of the Coburn Formation and the upper part of the Salona Formation are well exposed at the western edge of the village of Coburn in a cut on the north side of the secondary road leading to Spring Mills. The base of the Coburn is found at the northern end of a small abondoned quarry cut toward the western end of the exposure. The upper part of the Coburn is covered and the lower part of the Salona is poorly exposed. Beds strike about N. 80° E. and dip about 50° SE. The dip increases slightly toward the uppermost beds of the exposure.

Unit	*Lithologic description*	*Thickness* *Feet* *Unit*	 *Total*
	TRENTON GROUP		
	COBURN FORMATION		
	Coleville Member		
1.	Calcilutite, abundantly argillaceous, with few slabs of fine-grained calcarenite in slope debris. About 90% covered.	24	49
2.	Calcarenite (60%), in part laminated, alternating with argillaceous calcilutite (20%), and characterized especially by bioskeletal calcirudites (20%) that contain abundant *Sowerbyella* sp., *Dalmanella* sp., *Rafinesquina* sp. and fewer gastropods, trilobites, cephalopods and crinoid plates, in beds less than 3 inches thick. About 50% exposed.	7	25
3.	Calcilutite (50%), argillaceous, grayish black, in 6-inch beds, interlayered with fine-grained, partly laminated calcarenite (25%), as well as with abundantly argillaceous calcilutite. Basal two feet with several 2-inch crinoidal-bioskeletal calcirudites with abundant *Sowerbyella* sp., *Dalmanella* sp. and trilobite fragments. About 10% exposed.	18	18
	Thickness of exposed Coleville Member		49
	Milesburg Member		
4.	Calcilutite (50%), argillaceous, grayish black, in 6-inch beds, alternating with fine-grained calcarenite. *Sowerbyella*-trilobite bioskeletal calcirudite, 2 inches thick, at base. About 25% exposed.	8½	68¼
5.	Calcarenite (50%), in part laminated and cross-laminated, in 6-inch beds, alternating with argillaceous calcilutite and several 4-inch interlayers of *Sower-*		

	byella-trilobite bioskeletal calcirudite. Basal 1½ feet is calcareous shale with interlayers of argillaceous calcilutite.	7½	59¾
6.	Calcarenite (75%), fine-grained, partly laminated and cross-laminated, in 6-inch beds, interlayered with *Sowerbyella*-trilobite bioskeletal calcirudite (20%) and calcareous black shale. Top bed is 7-inch bioskeletal layer.	9½	52¼
7.	Calcilutite (75%) argillaceous, in 6-inch beds with few burrow-like structures, interlayered with fine-grained calcarenite, calcareous black shale and several *Sowerbyella*-trilobite bioskeletal calcirudites also rich in *Rafinesquina* sp.	12	42¾
8.	Calcilutite (50%), argillaceous, in 6-inch beds, interlayered with laminated and cross-laminated calcarenite (25%) and, in basal part, with calcareous shale in 1- to 4-inch beds. Calcarenites increase upward. *Sowerbyella*-trilobite bioskeletal calcirudites, with numerous *Rafinesquina* sp., in 2- to 3-inch beds, in upper one-half of unit.	15	30¾
9.	Metabentonite, yellowish-weathered, 3 inches thick, overlain by 7 inches of calcareous black shale.	¾	15¾
10.	Calcilutite (50%), argillaceous, grayish black, alternating with fine-grained calcarenite (30%), mostly in upper part, as well as with *Sowerbyella*-bioskeletal calcirudite (15%) with numerous crinoid plates, *Dalmanella* sp., bryozoans and trilobite fragments. Beds 4 to 6 inches thick with several shale interlayers.	6	15
11.	Calcarenite (50%), partly laminated and cross-laminated, interlayered with argillaceous calcilutite (40%), as well as with shale interlayers which may in part be bentonitic. Beds gently undulose, 2 to 4 inches thick. Fossils on bedding surfaces include *Rafinesquina* sp. unid. 2 feet above base, *Sowerbyella* sp. and recrystallized nautiloid cephalopods.	6	9
12.	Calcarenite (60%), partly laminated, interlayered with argillaceous calcilutite, calcareous black shale and bioskeletal calcirudite (10%), rich in *Sowerbyella* sp., *Dalmanella* sp. and *Rafinesquina* sp. Metabentonite, 1 inch thick, underlain by 4 inches of calcareous shale mark top of unit.	3	3
	Thickness of Milesburg Member		68¼
	Thickness of exposed Coburn Formation		117¼

SALONA

Roaring Spring Member

13.	Calcilutite, abundantly argillaceous, with several 1-inch interlayers of argillaceous calcilutite and calcarenite.	3½	194

14.	Metabentonite R, yellowish-weathered, 2 inches thick.	¼	190½
15.	Calcilutite, argillaceous, grayish black, in 2- to 4-inch beds, with ½-inch calcareous black shale interlayers between every bed. *Rafinesquina* sp. unid. at 7 feet below top; other *Rafinesquina* sp. throughout unit.	11	190¼
16.	Calcarenite, in part laminated or cross-laminated, interlayered with argillaceous calcilutite (40%) and with ½-inch shale layers between every bed. Bedding commonly 6 inches thick with several 10-inch beds in middle of unit. Generally unfossiliferous; *Rafinesquina* sp. unid., *Dalmanella* sp. and *Prasopora* (?) sp., 3 feet below top.	11½	179¼
17.	Metabentonite, 8 inches thick, overlain by 1½ feet of shale and argillaceous limestone.	2¼	167¾
18.	Calcilutite (60%), argillaceous, grayish black, unfossiliferous, in 2- to 3-inch, some 6-inch beds, interlayered with partly laminated and cross-laminated, fine-grained calcarenite (20%), as well as with calcareous shale. *Sowerbyella*-bioskeletal calcirudite, 1½ inches thick, at 4½ feet below top.	48	165½
19.	Calcilutite, argillaceous, grayish black, in 1- to 2-foot beds.	6½	117½
20.	Calcarenite, fine-grained, partly laminated and cross-laminated, in 3- to 4-foot beds. Several 1-inch layers of *Sowerbyella*-bioskeletal calcirudite in basal 2 feet. Few burrow-like structures.	6	111
21.	Calcarenite and interlayered argillaceous calcilutite in 2- to 7-inch beds, with *Parastrophia hemiplicata* at 6 inches above base.	5	105
	(The two units above represent a tongue of the Coburn Formation within the Roaring Spring Member of the Salona Formation.)		
22.	Concealed.	8	100
23.	Metabentonite, 1½ inches thick, overlain by calcareous shale and 1½ feet of argillaceous calcilutite with abundant burrow-like structures.	2	92
24.	Limestone, aphanitic to very-finely-crystalline, grayish black, in 6-inch beds, alternating with calcareous black shale (35%) as well as with several interlayers of calcarenite.	10	90
25.	Covered. Slabs of aphanitic, grayish black limestone, and partly laminated and cross-laminated, fine-grained calcarenite in float. Burrow-like structures in some beds.	38½	80
26.	Limestone, aphanitic to very-finely-crystalline, grayish black, in 6-inch beds, interlayered with several partly-laminated calcarenite beds. Metabentonite, 1 inch thick, at base.	1½	41½

27. Limestone, very-finely-crystalline, grayish black, interlayered with fine-grained calcarenite as in above unit. This unit structurally complicated.	19	40
28. Calcarenite, fine-grained, partly laminated and cross-laminated, in 2- to 4-inch beds. Mostly covered.	21	21
Thickness of Roaring Spring Member		194
New Enterprise Member		
29. Calcilutite, argillaceous, grayish black, in 6-inch to 1-foot beds, interlayered with abundantly argillaceous calcilutite (50%). Partly covered.	21	122½
30. Calcilutite, argillaceous, grayish black, in 1-foot beds, interlayered with abundantly argillaceous calcilutite (40%). Uppermost few inches is cherty limestone, probably overlain by a metabentonite. About 75% covered.	23	101½
31. Covered. Much abundantly argillaceous calcilutite in slope rubble. *Dalmanella* sp. scattered throughout.	20	78½
32. Calcilutite, argillaceous, grayish black, in 6-inch to 1-foot beds. Abundantly argillaceous calcilutite in upper five feet. Partly covered.	11	58½
33. Covered.	13	47½
34. Calcilutite, argillaceous, grayish black, in 6-inch to 1-foot beds. Abundantly argillaceous calcilutite, 2 feet thick, at 2 feet below top. Mostly covered.	15	34½
35. Covered.	13	19½
36. Calcilutite, argillaceous, with 25% of coarser crystals, presumably crinoid plates. Transitional into the underlying Rodman member. Mostly covered.	6½	6½
Thickness of New Enterprise Member		122½
Thickness of Salona Formation		316½
NEALMONT FORMATION		
Rodman Member		
Bioskeletal calcarenites in 2- to 3-inch nodular beds.	10	10
Measured thickness of Rodman Member		10

REEDSVILLE SECTION
(No. 11)

The Reedsville section is located in the Lewistown, Pennsylvania, quadrangle, about 4,750 feet west of 77° 35′ longitude and about 250 feet north of 40° 40′ latitude. Most of the Salona Formation is very well exposed in a road cut along the west side of Route 76 at the intersection with Route 322. The New Enterprise Member here is 96 feet thick and 161 feet of the Roaring Spring Member are exposed. This is the most complete exposure of the Roaring Spring

Member in central Pennsylvania. Beds strike about N. 63° E. and dip about 45° SE. The uppermost beds of the exposure dip more gently.

Unit	Lithologic description	Thickness	
		Feet	
		Unit	Total
TRENTON GROUP			
SALONA FORMATION			
Roaring Spring Member			
1.	Calcarenite, fine-grained, in part laminated and cross-laminated, medium dark gray, in 4-foot beds near base and 6-inch beds at top. Lower 2 feet is abundantly argillaceous calcilutite. *Sowerbyella* sp. on some bedding surfaces; burrow-like structures numerous.	15	161¼
2.	Metabentonite R, yellowish-weathered, 9 inches thick with 1-inch calcite layer at base.	¾	146¼
3.	Calcarenite (40%), fine-grained, in part laminated and cross-laminated, in alternation with argillaceous calcilutite (40%) and with 1- to 6-inch calcareous black shale interlayers which are thicker and more abundant in lowermost 8 feet. Several yellowish weathering dolomitic layers. Metabentonite, 1 inch thick, at base of shale layer, 8 feet above base. Limestone beds, 2 to 4 inches thick, are nodular; uppermost bed is 1 foot thick. *Dalmanella* sp. abundant on uppermost bedding surface; *Sowerbyella* sp. and *Cryptolithus tesselatus* rare; burrow-like structures abundant.	35	145½
4.	Metabentonite, yellowish-weathered, 1 inch thick, at base of 6-inch calcareous shale layer.	½	110½
5.	Calcilutite, argillaceous, grayish black, commonly in 1- to 2-foot beds, alternating with fine-grained calcarenite (10%) as well as with several 4-inch yellowish weathering dolomitic limestone beds. Several ½-inch crinoidal calcarenites at 6½ to 7½ feet above base; *Parastrophia hemiplicata* at 7½ feet above base; *Sowerbyella* sp., *Rafinesquina* sp. and gastropods rare.	13½	110
6.	Calcilutite (60%), abundantly argillaceous, grayish black, in 1- to 1½-foot beds, in alternation with 2- to 6-inch beds of very-finely-crystalline limestone (25%) and partly-laminated, fine-grained calcarenite. Several dolomitic limestone layers at 12 feet below top. Argillaceous layers spaced from 3 to 5 feet apart. *Prasopora* (?) sp., *Rafinesquina* sp., *Sowerbyella* sp. in upper 5 feet; scattered recrystallized nautiloid cephalopods.	28½	96½
7.	Calcilutite (75%), argillaceous, grayish black, in 2- to 4-inch irregular beds, in alternation with partly laminated and		

	cross-laminated, fine-grained calcarenite (15%) as well as with abundantly argillaceous calcilutite and ½-inch shale interlayers between each limestone bed. *Sowerbyella* sp. in basal one-half; *Leptaena* sp. in middle.	26	68
8.	Calcilutite (50%), argillaceous, grayish black, alternating with abundantly argillaceous calcilutite (30%) and partly laminated and cross-laminated, fine-grained calcarenite (20%). Abundantly argillaceous calcilutite comprises 50% of lower 10 feet. Beds 3 to 6 inches thick. *Dalmanella* sp. and *Sowerbyella* sp. rare.	26	42
9.	Calcilutite, argillaceous, grayish black, in 1-foot beds.	3	16
10.	Metabentonite, yellowish-weathered, 5 inches thick.	½	13
11.	Calcilutite, argillaceous, grayish black, in 6-inch to 1-foot beds, with interlayers of partly laminated and cross-laminated, fine-grained calcarenite. Basal 1½ feet is abundantly argillaceous calcilutite. Several calcareous black shale interlayers in middle. Siliceous limestone in upper 4 inches. *Sowerbyella* sp., *Cryptolithus tesselatus, Dalmanella* sp. rare.	7	12½
12.	Metabentonite No. 5, yellowish-weathered, 4 inches thick, overlain by 1 inch of calcareous shale.	½	5½
13.	Calcilutite (50%), abundantly argillaceous, grayish black, in 6-inch, some 1½-foot, beds alternating with argillaceous calcilutite (30%) as well as with partly laminated, fine-grained calcarenite. At base is an 8-inch, strongly laminated calcarenite layer. *Sowerbyella* sp., *Dalmanella* sp., *Isotelus* sp. rare.	5	5
	Thickness of exposed Roaring Spring Member		161¼
	New Enterprise Member		
14.	Calcilutite (90%), argillaceous, grayish black, in 1-foot beds, with interlayers of abundantly argillaceous calcilutite (10%). *Homalonotus trentonensis* especially in argillaceous layers; *Isotelus* sp., brachiopods and cephalopods rare.	17½	96¼
15.	Calcilutite, argillaceous, grayish black, in 4- to 6-inch beds, with abundantly argillaceous calcilutite in lower 1½ feet. *Homalonotus trentonensis, Sowerbyella* sp. rare.	5	78¾
16.	Metabentonite No. 4, yellowish-weathered, 8 to 10 inches thick, overlain by 1½ feet of calcareous black shale.	2¼	73¾
17.	Calcilutite, argillaceous, very dark gray, in 6-inch to 1-foot beds, with several interlayers of abundantly argillaceous calcilutite. Brachiopods rare.	8	71½
18.	Calcilutite, abundantly argillaceous, grayish black, in 1- to 4-inch beds. Cephalopods rare.	7	63½

19.	Calcilutite, argillaceous, grayish black, in 4- to 6-inch beds, with several interlayers of abundantly argillaceous calcilutite. Basal 2 feet is medium-crystalline limestone.	12	56½
20.	Metabentonite No. 3, yellowish-weathered, 10 inches thick, overlain by 1½ inches of calcareous black shale.	1	44½
21.	Calcilutite, argillaceous, very dark gray, in 4- to 6-inch, some 1-foot beds, with numerous interlayers of abundantly argillaceous calcilutite. *Cryptolithus tesselatus* and *Isotelus* sp. rare. Partly covered.	17	43½
22.	Metabentonite No. 2, yellowish-weathered, 4 inches thick.	¼	26½
23.	Calcilutite, argillaceous, very dark gray, in 4- to 9-inch beds, with cherty limestone in upper 2 inches.	1¾	26¼
24.	Metabentonite No. 1, yellowish-weathered, 6 inches thick.	½	24½
25.	Calcilutite, argillaceous, very dark gray, in 4- to 6-inch beds. Lower one-half with 10% to 25% of coarse crinoid plates and several 1-inch crinoidal calcarenite layers. Mostly covered; base approximate.	24	24
	Thickness of New Enterprise Member		96¼
	Thickness of exposed Salona Formation		257½
	NEALMONT FORMATION		
	Rodman Member		
	Calcarenite, crinoidal, in 1- to 3-inch nodular beds.	4	4
	Measured thickness of Rodman Member		4

REEDSVILLE SECTION

(No. 12)

The Reedsville section is located in the Lewistown, Pennsylvania, quadrangle, about 10,500 feet east of 77° 40′ longitude and about 5,750 feet south of 40° 40′ latitude. The section description is the record of a core (Hole No. C-1) drilled by and filed with the Pennsylvania Department of Forests and Waters along the southeastern side of Route 76 which leads to Belleville. The core penetrated the uppermost 71 feet of the Roaring Spring Member of the Salona Formation and the lower 69 feet of the Coburn Formation.

Unit	*Lithologic description*	*Thickness* *Feet*	
		Unit	*Total*
	TRENTON GROUP		
	COBURN FORMATION		
1.	Calcilutite, abundantly argillaceous, grayish black, with interlayers of calcareous black shale. Several ½- to 1-		

	inch interlayers of crinoidal bioskeletal calcirudite at 3 to 5 feet above base. Burrow-like structures in upper part.	5	68½
2.	Calcilutite, abundantly argillaceous, black, with interlayers of calcarenite (10%), as well as several 1- to 2-inch interlayers of brachiopod-rich bioskeletal calcirudite. *Rafinesquina* sp. rare.	6½	63½
3.	Calcarenite, partly laminated and cross-laminated, medium dark gray, with numerous interlayers of calcareous shale as well as brachiopod-rich bioskeletal calcirudite. Burrow-like structures numerous in lower 12 feet.	30	57
4.	Calcarenite, partly laminated and cross-laminated, fine-grained, medium dark gray, with abundant interlayers of calcareous shale (25%) and argillaceous calcilutite. Several interlayers of crinoidal-bioskeletal calcirudite.	6½	27
5.	Shale, calcareous, 3 inches thick, slickensided. Perhaps a metabentonite layer.		
6.	Calcarenite, partly laminated and cross-laminated, fine-grained, medium dark gray, with interlayers of calcareous black shale, up to 4 inches thick, as well as numerous interlayers of brachiopod-rich bioskeletal calcirudite, up to 2 inches thick. *Prasopora* (?) sp. and burrow-like structures rare.	8	20½
7.	Calcarenite, partly laminated and cross-laminated, fine-grained, medium dark gray, with few widely spaced, ½-inch bioskeletal calcirudite layers, and numerous interlayers of sparsely fossiliferous calcareous shale.	12½	12½
	Thickness of measured Coburn Formation		68½

SALONA FORMATION

Roaring Spring Member

8.	Calcarenite, partly-laminated and cross-laminated, fine-grained, medium dark gray, in 4- to 6-inch beds, with several interlayers of abundantly argillaceous calcilutite and calcareous shale. Burrow-like structures rare.	22	71½
9.	Metabentonite, 8 inches thick, with a 1-inch calcite layer at base.	½	49½
10.	Calcarenite (75%), partly laminated and cross-laminated, in 3- to 8-inch beds, with interbeds of argillaceous calcilutite and calcareous shale. *Prasopora* (?) sp. and burrows rare.	15½	49
11.	Calcilutite, argillaceous, grayish black, with numerous interlayers of calcareous shale and several interlayers of partly laminated, fine-grained calcarenite. Burrows common in upper 10 feet.	18	33½
12.	Calcilutite, abundantly argillaceous, in part laminated, grayish black, in 1- to 3-foot beds, with several interlayers of fine-grained calcarenite.	12½	15½

13.	Metabentonite R, 8 inches thick, overlain by 4 inches of black shale and underlain by 1-inch layer of calcite.	1	3
14.	Calcilutite, abundantly argillaceous, black, as in unit 12.	2	2
	Thickness of measured Roaring Spring Member		71½
	Thickness of penetrated Salona Formation		71½

COLERAIN SECTION

(No. 13)

The Colerain section is located in the Tyrone, Pennsylvania, quadrangle, about 16,000 feet north of 40° 35′ latitude and about 8,000 feet west of 78° 05′ longitude. The section is located on the northern side of Route 45 just east of the entrance to Colerain State Park. Beds of the uppermost 140 feet of the Roaring Spring Member are continuously exposed at this locality, whereas beds of the lower part of the Milesburg Member are poorly exposed. Beds strike about N. 68° E and dip about 39° SE.

Unit	*Lithologic description*	*Thickness* *Feet* *Unit*	*Thickness* *Feet* *Total*
TRENTON GROUP			
COBURN FORMATION			
Milesburg Member			
1.	Covered.		
2.	Calcarenite, partly laminated, fine-grained, with a 4-inch interlayer of *Sowerbyella*-trilobite bioskeletal calcirudite at top.	1½	49
3.	Concealed.	16	47½
4.	Metabentonite R, 1½ inches thick, overlain by at least 1½ feet of shale.	1½	31½
5.	Calcilutite, argillaceous, black, in 3- to 9-inch partly undulose beds, with numerous interlayers of partly laminated and cross-laminated, fine-grained calcarenite, and less numerous interlayers of Sowerbyella bioskeletal calcirudite which increase upward in number. Several prominent shale beds in middle of unit, some of which may be bentonitic. *Prasopora* (?) sp., *Dalmanella* sp., *Rafinesquina* sp. unid. and crinoid stems fairly common in upper one-half of unit.	30	30
	Exposed thickness of Milesburg Member		49
	Exposed thickness of Coburn Formation		49
SALONA FORMATION			
Roaring Spring Member			
6.	Calcilutite, argillaceous, black, in 3- to 9-inch in part undulose beds, with nu-		

	merous interlayers of partly laminated and cross-laminated, fine-grained calcarenite (40%), and widely-scattered ½-inch lenses of bioskeletal calcirudite. Interbeds of calcareous shale, in upper one-half. *Sowerbyella* sp. and trilobite fragments rare; burrow-like structures common in upper one-half.	27½	139½
7.	Calcilutite, argillaceous, grayish black, in 2- to 4-inch beds, with numerous interlayers of *Sowerbyella* bioskeletal calcirudite (25%) as well as laminated and cross-laminated calcarenite. Beds tightly cemented, with shaly partings. Pyrite abundant in some bioskeletal layers. *Parastrophia hemiplicata* rare near top; burrows abundant; crinoids and other brachiopods rare; bioskeletal layer of bryozoans at 10 feet above base. This unit is regarded as an intertongue of the Coburn formation in the Roaring Spring member.	23½	112
8.	Calcilutite, argillaceous, black, in 3- to 6-inch beds, with numerous interlayers of fine-grained calcarenite, in part laminated, which increase in number in upper one-half of unit. Some beds undulose or ripple-marked. Thin shaly partings between most limestone beds. Burrow-like structures common near top; brachiopods rare.	17½	88½
9.	Metabentonite, yellowish-weathered, 2 inches thick.		
10.	Calcilutite, argillaceous, in 4- to 6-inch beds with several interlayers of laminated, fine-grained calcarenite. *Prasopora* (?) sp. and brachiopods near top.	2½	71
11.	Metabentonite, yellowish-weathered, 4 inches thick.		
12.	Calcilutite, argillaceous, commonly in 4- to 6-inch beds with some 1-foot beds in upper part, with numerous interlayers of abundantly laminated and cross-laminated, fine-grained calcarenite, and rarer layers of calcareous shale. Numerous yellowish weathering, dolomitic limestone bands in upper 10 feet. Many beds ripple-marked or undulose. Black chert nodules, 1½ inches in diameter, in uppermost bed. Abundant pyrite cubes in laminae near middle of unit. *Cryptolithus tesselatus, Sowerbyella* sp., *Dalmanella* sp., trilobite fragments, gastropods, bryozoans, cephalopods and crinoid plates rare and occur mostly on bedding surfaces in upper one-half of unit.	41½	68½
13.	Metabentonite No. 5 (?), 6 inches thick.	½	27
14.	Calcilutite, argillaceous, in 4- to 6-inch, some 1-foot, beds, with several interlayers of laminated and cross-laminated, fine-grained calcarenite. *Homalonotus*		

trentonensis in bottommost bed; *Cryptolithus tesselatus* and brachiopods rare.	26½	26½
Exposed thickness of Roaring Spring Member		139½
Exposed thickness of Salona Formation		139½

UNION FURNACE SECTION

(No. 14)

The Union Furnace section is located in the Tyrone, Pennsylvania, quadrangle, about 14,000 feet north of 40° 35′ latitude and along the 78° 10′ longitude line. The section is located north of the crushing plant between the eastern and western sections of the Warner Company quarry, about three-quarters of a mile north of Union Furnace on Route 322. The Salona Formation and the lower 202 feet of the Coburn Formation are completely exposed, and the beds stand nearly vertical.

Unit	*Lithologic description*	*Thickness* *Feet* *Unit*	*Thickness* *Feet* *Total*
TRENTON GROUP			
COBURN FORMATION			
Milesburg Member			
1.	Mostly concealed. Few slabs of calcirudite in rubble contain *Sowerbyella* sp. and some trilobite fragments.	40	202
2.	Metabentonite R, 14 inches of yellowish-weathered clay overlain by 15 inches of black, calcareous shale.	2½	162
3.	Calcarenite, laminated and cross-laminated, and slabs of *Sowerbyella* bioskeletal calcirudite in slope rubble. Gastropods numerous in bioskeletal layers. Poorly exposed.	25½	159½
4.	Metabentonite zone consisting of three thin bentonites separated by argillaceous calcilutite.	1	134
5.	Calcilutite, argillaceous, in 4- to 6-inch, some 1-foot, beds, with numerous interlayers of laminated and cross-laminated calcarenite, and several bands and lenses of *Sowerbyella* bioskeletal calcirudite. Crinoidal layer, ¾-inch thick, at 10 feet below top.	39½	133
6.	Calcarenite, in part laminated and cross-laminated, in 3- to 5-inch, some 1-foot, beds, with numerous interbeds of argillaceous calcilutite, and *Sowerbyella* bioskeletal calcirudite. Some beds are undulose or ripple-marked. Partings of calcareous shale, less than 1 inch thick, between most limestone layers. Bioskeletal layers rare at 5 to 16 feet and 24 to 32 feet above base, and generally increase in number upward. Black chert nodules, 1 inch in diameter, at 3 feet above base. Bryozoans numer-		

ous at 22 feet above base; burrow-like structures numerous throughout unit; *Dalmanella* sp. and cephalopods rare. Bioskeletal layer, 4½ inches thick, with trilobite fragments and bryozoans, at 35 feet above base. Top of unit marked by 1½ feet of calcirudite comprised of *Sowerbyella* sp., crinoid plates and several specimens of *Rafinesquina* sp. unid.	71½	93½
7. Calcarenite, in part laminated and cross-laminated, in 4- to 8-inch beds, with interlayers of argillaceous calcilutite, *Sowerbyella* bioskeletal calcirudite, and calcareous shale. Few bands of dolomitic limestones at 4 to 6 feet above base. Some limestone beds undulose or ripple-marked. Calcareous shales decrease upward in abundance. Bioskeletal layers rare in lower 10 feet, contain abundant pyrite cubes. *Cryptolithus tesselatus* at 5 feet above base; numerous recrystallized cephalopods and pelecypods at 14 to 18 feet above base; gastropods, crinoid plates, *Dalmanella* sp. and *Rafinesquina* sp. rare.	22	22
Exposed thickness of Milesburg Member		202
Exposed thickness of Coburn Formation		202

SALONA FORMATION

Roaring Spring Member

8. Calcilutite, argillaceous, black, in 4- to 8-inch beds, with interlayers of laminated and cross-laminated, fine-grained calcarenite. Some beds are undulose or ripple-marked. *Cryptolithus tesselatus* at 1 foot below top.	6	70½
9. Metabentonite No. 5 (?), 5 inches thick, overlain by calcareous black shale and interlayers of abundantly argillaceous calcilutite.	1½	64½
10. Calcarenite, in part laminated and cross-laminated, in 1-foot beds, in alternation with interlayers of argillaceous calcilutite and calcareous shale. Numerous 1- to 4-inch bands of dolomitic limestone in upper 18 feet. Black chert nodules, up to 3 inches in diameter, at 10 feet above base; cherty limestone in uppermost 2 inches. *Dalmanella* sp. and *Cryptolithus* rare.	34	63
11. Calcarenite, in part laminated and cross-laminated, fine-grained, in 8- to 10-inch beds, in alternation with calcilutite, and calcareous shale. Shale layers, up to 4 inches thick, between most limestone layers. Some beds at top strongly ripple-marked, with 2-foot wave lengths and 6- to 10-inch amplitudes. No fossils observed.	19	29
12. Calcarenite, in part laminated and cross-laminated, fine-grained, in 4- to 6-inch beds, with several interbeds of abun-		

	dantly argillaceous calcilutite. Pyrite cubes in laminae at 10 feet above base. *Homalonotus trentonensis, Dalmanella* sp., at 6 and 10 feet above base; burrow-like structures sparse.	10	10
	Thickness of Roaring Spring Member		70½
New Enterprise Member			
13.	Calcilutite, argillaceous, black, in 1-foot beds, with several 1- to 2-inch interlayers of calcareous shale 17 to 22 feet above base. Black chert layer, ½ inch thick, at 9 feet above base. *Homalonotus trentonensis* at 22 feet above base; *Dalmanella* sp., *Prasopora* (?) sp., crinoid plates mostly on bedding surfaces of upper beds.	27½	108½
14.	Metabentonite No. 5 (?), 1 inch thick, overlain by calcareous shale.	½	81
15	Calcilutite, argillaceous, black, in 6-inch to 1-foot beds, *Dalmanella* sp., recrystallized cephalopods and crinoid plates rare.	6½	80½
16.	Metabentonite No. 4, overlain by calcareous shale.	2	74
17.	Calcilutite, argillaceous, black, in 4- to 8-inch beds, with numerous interlayers of abundantly argillaceous calcilutite in upper 20 feet. *Cryptolithus tesselatus, Isotelus* sp., *Sowerbyella* sp., cephalopods and crinoid plates rare on some bedding surfaces. Uppermost bed 15 inches thick with numerous fossils, including a 3½-foot cephalopod on upper surface.	27	72
18.	Metabentonite No. 3, 2½ inches thick.		
19.	Calcilutite, argillaceous, black, in 4- to 10-inch beds, with few interlayers of abundantly argillaceous calcilutite. *Cryptolithus tesselatus,* small gastropods and burrows rare.	10	45
20.	Calcilutite, argillaceous, black, in 2- to 3-foot beds, with numerous interlayers of abundantly argillaceous calcilutite (50%), as well as a few interlayers of calcareous shale. Two thin bioskeletal lenses at 6 to 7 feet above base. Black chert nodules, 3 inches in diameter, in upper 3 feet. *Isotelus* sp., crinoid plates, brachiopods, cephalopods rare. Some fossils are pyritized.	13	35
21.	Calcilutite, abundantly argillaceous, black, in 8- to 11-inch beds, with several interlayers of argillaceous calcilutite, as well as calcareous shales. Beds 2 feet thick in upper part. *Cryptolithus tesselatus* rare in upper 7 feet; brachiopods and crinoid plates rare.	12	22
22.	Metabentonite No. 2, 4 inches thick.	½	10
23.	Calcilutite, abundantly argillaceous, in 8- to 10-inch beds. Uppermost 3 inches are cherty limestone. Brachiopods rare.	1½	9½
24.	Metabentonite No. 1, 1 inch, overlain by 3 inches of shale.		

25.	Calcilutite, argillaceous, medium dark gray, in 1- to 4-inch, somewhat irregular, beds. Abundance of crinoid plates makes this unit appear transitional between Rodman and Salona. Cephalopods abundant at 6 feet above base.	8	8
26.	Metabentonite No. 0, 1-inch parting of yellowish clay.		
	Thickness of New Enterprise Member		108½
	Thickness of Salona Formation		189
NEALMONT FORMATION			
Rodman Member			
	Calcarenite, crinoidal, in 1- to 3-inch nodular beds.	10	10
	Measured thickness of Rodman Member		10

ROARING SPRING SECTION

(No. 15)

The Roaring Spring section is located in the Hollidaysburg, Pennsylvania, quadrangle, about 4,000 feet east of 78° 25′ longitude and about 5,250 feet north of 40° 20′ latitude. The Salona and Coburn Formations are exposed entirely at the northwestern margin of the New Enterprise Company quarry located about three-fourths of a mile north of the town of Roaring Spring and near the town of Rodman. The Roaring Spring section has been selected by the writer as a reference section for the Salona Formation in central Pennsylvania, and as the type section for the New Enterprise and Roaring Spring Members. At this locality, the Salona Formation is 166 feet thick. The New Enterprise Member comprises the lower 90 feet of the formation and the Roaring Spring Member comprises the upper 76 feet. The Coburn at this locality is 170 feet thick. In the Salona Formation, the beds are nearly vertical, but become increasingly overturned toward the upper part of the Coburn Formation where they dip about 45° SE.

Unit	*Lithologic description*	*Thickness*	
		Feet	
		Unit	*Total*
RENTON GROUP			
ANTES SHALE			
1.	Calcareous shale (60%), black, with 6-inch to 1-foot interlayers of argillaceous calcilutite, grayish black, spaced from a few feet to a few inches apart, but absent from upper 10 feet of unit. *Triarthus* sp. in upper 15 feet; *Cryptolithus tesselatus* at 15 to 35 feet below top.	87	87
	Measured part of Antes shale		87

COBURN FORMATION

Coleville Member

2. Calcarenite (60%), fine-grained, laminated and cross-laminated, in 4- to 8-inch beds, alternating with bioskeletal calcirudites (25%) rich in *Sowerbyella* sp., crinoid plates and *Dalmanella* sp., as well as with several interlayers of grayish black argillaceous calcilutite and calcareous shale. Base of unit marked by crinoidal bioskeletal calcirudite, 10 inches thick, overlain by 8-inch bed of *Sowerbyella* bioskeletal calcirudite. *Dalmanella* sp. on many bedding surfaces.	26	26
Thickness of Coleville Member		26

Milesburg Member

3. Calcarenite (40%), fine-grained, laminated and cross-laminated, in 4- to 6-inch undulose beds, with interlayers of argillaceous calcilutite and *Sowerbyella*-trilobite bioskeletal calcirudite (10-20%). Unit marked by numerous calcareous shale interlayers up to 5 inches thick. *Rafinesquina* sp. common; burrow-like structures abundant.	12	144
4. Calcarenite (60%), fine-grained, abundantly laminated and cross-laminated, in 4- to 8-inch gently undulose beds which are nodular in places, in alternation with argillaceous calcilutite, mostly in lower one-half, as well as with 1- to 3-inch interlayers of *Sowerbyella*-trilobite bioskeletal calcirudite (10-15%). Calcareous shales between every limestone bed. Several irregular dolomitic limestone bands at 8 feet above base. *Rafinesquina* sp., gastropods, fairly common; burrows abundant.	25	132
5. Metabentonite R, yellowish-weathered, 3 inches thick, overlain by 2¼ feet of calcareous black shale with several limestone interbeds.	2½	107
6. Calcarenite (60%), fine-grained, abundantly laminated and cross-laminated, in 2- to 4-inch gently undulose beds, in alternation with *Sowerbyella* bioskeletal calcirudite (10-20%), argillaceous calcilutite and numerous 1-inch calcareous shale beds. Uppermost limestone bed, 1½ feet thick. Few trilobite fragments; numerous burrow-like structures and brachiopods.	16	104½
7. Metabentonite, yellowish-weathered, 2 inches thick, overlain by calcareous black shale with several 1-inch limestone interlayers.	1	88½
8. Calcarenite (60%), fine-grained, partly laminated and cross-laminated, in 2- to 5-inch gently undulose beds, with 1- to 4-inch interlayers of *Sowerbyella* bioskeletal calcirudite (20%), as well as		

	with argillaceous calcilutite and 1-inch beds of calcareous shale between each limestone layer. Uppermost bed is bioskeletal calcirudite with siliceous bands that stand in relief. Brachiopods, crinoid plates and *Isotelus* sp. common; burrows abundant.	23½	87½
9.	As unit above, but in 6- to 10-inch beds, and with 30% of bioskeletal calcirudite. Gastropods and bryozoans common.	13	64
10.	Calcilutite (50%), argillaceous, grayish black, with interlayers of partly laminated, fine-grained calcarenite, as well as with ½- to 3-inch beds of *Sowerbyella* bioskeletal calcirudite which increase in number in upper one-half of unit. Beds commonly 5 to 7 inches thick in lower one-half and 2 to 5 inches thick near top. Crinoid plates and *Rafinesquina* sp. common; *Rafinesquina* sp. unid. in upper part; *Cryptolithus tesselatus* in upper few feet; burrows abundant.	38½	51
11.	Metabentonite, yellowish-weathered, 1 inch thick.		
12.	Calcilutite (60%), argillaceous, grayish black, in 4- to 6-inch beds, with interlayers of partly laminated fine-grained calcarenite (20%) and 1-inch *Sowerbyella* bioskeletal bands and stringers (5%). *Dalmanella* sp., *Isotelus* sp., crinoid plates, gastropods and bryozoa in moderate numbers on bedding surfaces and in bioskeletal layers; burrows numerous. Calcareous black shale (15%) between every limestone bed.	1½	12½
13.	Metabentonite, yellowish-weathered, 2 inches thick, overlain by calcareous black shale with thin interbeds of laminated, fine-grained calcarenite.	½	11
14.	Calcarenite (60%), fine-grained, partly laminated and cross-laminated, commonly in 6- to 8-inch with some 1½-foot beds, with interlayers of argillaceous calcilutite (25%), calcareous shale (15%) and ½-inch bands and stringers of *Sowerbyella* bioskeletal calcirudite (5%). Base marked by a prominent 2-inch horizon of recrystallized pelecypods which appear as calcite-filled vugs, about 1 inch in diameter. Uppermost bed 1¼ feet thick with bioskeletal layer at top. *Dalmanella* sp., *Isotelus* sp., crinoid plates, gastropods, cephalopods and trilobites moderate in number; burrows fairly abundant.	10½	10½
	Thickness of Milesburg Member		144
	Thickness of Coburn Formation		170

SALONA FORMATION

Roaring Spring Member

15.	Calcilutite, argillaceous, in 4- to 6-inch, some 1-foot, beds, with interbeds of laminated and cross-laminated fine-grained		

	calcarenite (25%) as well as ½- to 2-inch calcareous shale beds (15%). Black chert nodules 1½ to 2 inches in diameter in upper 5 feet. *Cryptolithus tesselatus*, *Prasopora* sp., *Dalmanella* sp., and *Sowerbyella* sp. rare; several ½-inch crinoidal stringers in upper 5 feet.	34¾	75½
16.	Metabentonite, yellowish-weathered, 8 inches thick, overlain by calcareous shale and limestone lenses.	¾	40¾
17.	Calcilutite (60%), argillaceous, grayish black, with interbeds of laminated and cross-laminated, fine-grained calcarenite (25%) as well as calcareous shale (15%). Abundant pyrite in laminae and cross-laminae in basal 10 feet. Beds commonly 4 to 6 inches thick, with some 1-foot beds; beds in basal 4 feet are 2 to 6 inches thick. Beds appear thinner in weathered part of outcrop. Brachiopods, recrystallized nautiloid cephalopods, crinoid plates are rare in upper part of unit; linguloid brachiopods in shales near base.	40	40
	Thickness of Roaring Spring Member		75½
New Enterprise Member			
18.	Calcilutite, argillaceous, structureless, grayish black, in 10-inch to 1½-foot beds.	3½	90
19.	Metabentonite No. 5 (?), yellowish-weathered, 1 inch thick.		
20.	Calcilutite, argillaceous, structureless, grayish black, in 10-inch to 1½-foot beds, with several interbeds of abundantly argillaceous calcilutite in basal 5 feet. *Homalonotus trentonensis* rare.	7½	86½
21.	Calcilutite, abundantly argillaceous, in 8-inch to 1-foot beds, with several argillaceous calcilutite interlayers at 10 feet above base and several 1-inch calcareous shale interlayers. *Homalonotus trentonensis*, *Rafinesquina* sp. and brachiopods rare. Pyritic layer, ½ inch thick, at 5 feet above base.	26½	79
22.	Calcilutite, abundantly argillaceous, grayish black, in 6-inch to 1-foot beds, in alternation with argillaceous calcilutite (40%) as well as with numerous calcareous shale beds up to 1½ inches thick.	5¾	52½
23.	Metabentonite No. 4, yellowish-weathered, 8 inches thick.	¾	46¾
24.	Calcilutite, argillaceous, structureless, dark gray, in two massive 1½-foot beds.	3	46
25.	Calcilutite, abundantly argillaceous, dark gray, in 1-foot beds. Crinoid plates numerous.	8	43
26.	Calcilutite, argillaceous, structureless, dark gray to grayish black, in 4-inch to 1½-foot beds separated by 1-inch calcareous shale interlayers. Abundantly argillaceous calcilutite layer, 1 foot thick, at 9½ feet above base.	13¾	35

27. Metabentonite No. 3, yellowish-weathered, 3½ inches thick, overlain by 6 inches of calcareous shale with *Cryptolithus tesselatus,* brachiopods and graptolite (?) fragments.	¾	21¼
28. Calcilutite, abundantly argillaceous, grayish black, in 6-inch to 1-foot beds, with interbeds of argillaceous calcilutite (40%). *Isotelus* sp. at 4½ feet above base.	9½	20½
29. Metabentonite No. 2, yellowish-weathered, 6 inches thick, overlain by 3 inches of calcareous shale.	¾	11
30. Limestone, cherty, finely crystalline to medium crystalline, grayish black, with numerous perpendicular fractures along which the rock breaks into polygonal fragments.	½	10¼
31. Metabentonite No. 1, yellowish-weathered, 3 inches thick.	¼	9¾
32. Calcilutite, abundantly argillaceous, grayish black, in 4- to 6-inch beds, alternating with argillaceous calcilutite. Uppermost bed 1 foot thick. Brachiopods rare.	5¼	9½
33. Metabentonite No. 0, yellowish-weathered, 2 inches thick.	¼	4¼
34. Calcilutite, argillaceous, structureless, with 10% to 25% of coarser cleavage faces, commonly in 4- to 6-inch beds with several 2- to 4-inch nodular beds. Numerous ½-inch calcareous shale interlayers. *Sowerbyella* sp. on uppermost surface. Unit is transitional between New Enterprise Member and underlying Rodman Member.	4	4
Thickness of New Enterprise Member		90
Thickness of Salona Formation		165½
NEALMONT FORMATION		
Rodman Member		
Limestone, crinoidal calcarenite in part, in 1½- to 2½-foot beds with abundant irregular shale partings spaced from 2 to 3 inches apart along which beds part upon weathering into the characteristic nodular beds of the Rodman.	7	7
Measured thickness of Rodman Member		7

ASHCOM SECTION

(No. 16)

The Ashcom section is the southwesternmost section in the area of udy and is located in the Bedford, Pennsylvania, quadrangle, about 0 feet north of 40° 00′ latitude and about 1,000 feet west of 78° ′ longitude. The Salona Formation and the lower part of the Coburn rmation are discontinuously exposed on the surface at the top of the New Enterprise Company quarry immediately south of the Pennsylvania Turnpike near the village of Ashcom. The Salona Formatio is about 160 feet thick at this locality.

Unit	Lithologic description	Thickness Feet Unit	Thickness Feet Total
TRENTON GROUP			
COBURN FORMATION			
1.	Covered.		
2.	Calcarenite, abundantly laminated and cross-laminated, fine-grained, with several interbeds of calcilutite and calcareous shale, and a few 1-inch bands of *Sowerbyella* bioskeletal calcirudite. Burrow-like structures numerous; *Cryptolithus tesselatus* rare at 10 feet above base.	50	50
	Exposed thickness of Coburn Formation		50
SALONA LIMESTONE			
Roaring Spring Member			
3.	Covered.	5	91
4.	Metabentonite R (?), yellowish-weathered.	1	86
5.	Limestone, weathered.	5	85½
6.	Calcilutite, argillaceous, in 6- to 8-inch beds, with interbeds of calcarenite (20%), in part laminated, and of abundantly argillaceous calcilutite. *Cryptolithus tesselatus* abundant in ½-inch layer at 8 feet above base. *Rafinesquina* sp. unid. in float at 10 feet above base.	16½	80½
7.	Metabentonite, overlain by 6 inches of calcareous shale.	½	64
8.	Calcilutite, argillaceous, black, in 4- to 6-inch, some 2-inch, beds, with several interlayers of abundantly argillaceous calcilutite as well as laminated and cross-laminated calcarenite (5%). *Cryptolithus tesselatus* and crinoid plates rare.	28	63½
9.	Metabentonite (?), yellowish-weathered, 3 inches thick.		
10.	Calcilutite, argillaceous, black, in 2- to 4-inch beds, with interlayers of laminated calcarenite (10%), as well as a few ½-inch bands of bioskeletal calcirudite rich in *Dalmanella* sp., *Sowerbyella* sp. and crinoids. *Cryptolithus tesselatus* rare.	10	35½
11.	Calcilutite, argillaceous, mostly concealed.	5½	25½
12.	Metabentonite, yellowish-weathered, 3 inches thick.		
13.	Calcilutite, argillaceous, black, in 2- to 4-inch beds, with several interlayers of		

laminated and cross-laminated, fine-grained calcarenite.	20	20
Thickness of Roaring Spring Member		91
New Enterprise Member		
14. Calcilutite, argillaceous, black, in 4- to 8-inch beds. *Homalonotus trentonensis* at 9 feet above base.	14½	69½
15. Metabentonite No. 5, yellowish-weathered, 6 to 8 inches thick.	½	55
16. Calcilutite, argillaceous, black, in 1- to 2-foot beds, with interlayers of abundantly argillaceous calcilutite (20%). *Homalonotus trentonensis* at 5 feet below top; *Rafinesquina alternata* rare. Burrow-like structures numerous in some beds.	24	54½
17. Metabentonite No. 4, yellowish-weathered, 6 inches thick, overlain by 6 inches of calcareous shale.	1	30½
18. Calcilutite, argillaceous, black, in 1- to 3-foot beds, with 6-inch beds in upper 4 feet. *Cryptolithus tesselatus, Sowerbyella* sp., crinoids rare.	14½	29½
19. Metabentonite No. 3, yellowish-weathered.	½	15
20. Calcilutite, abundantly argillaceous, black, in 1-foot beds.	2	14½
21. Metabentonite No. 2, yellowish-weathered.	1	12½
22. Limestone, cherty.	½	11½
23. Metabentonite No. 1, yellowish-weathered, 4 inches thick.	½	11
24. Calcilutite, abundantly argillaceous, black, in 6-inch beds, with interlayers of argillaceous calcilutite.	10½	10½
Thickness of New Enterprise Member		69½
Thickness of Salona Formation		160½
NEALMONT FORMATION		
Rodman Member		
Calcarenite, crinoidal, in 1- to 4-inch nodular beds.	10	10
Measured thickness of Rodman Member		10

SHADE GAP SECTION

(No. 17)

The Shade Gap section is located in Black Log Valley in the north central part of the Orbisonia, Pennsylvania, quadrangle, at about one-half mile north of Shade Gap Station along Route 35. The Salona Formation is about 375 feet thick at this locality and for the most part is well-exposed along a farm lane leading southeastward from Route 35. The lower 100 feet and the upper 45 feet of the formation are mostly concealed. The Coburn Formation is less than 50 feet thick at Shade Gap, and about 18 feet of it are exposed in a cut on the northwestern side of Route 35, opposite the farm lane.

Unit	*Lithologic description*	*Thickness* *Feet*	
		Unit	*Total*
TRENTON GROUP			
ANTES SHALE			
	Shale, calcareous, black.	20	20
	Measured thickness of Antes shale		20
	Concealed. Contact of Coburn Formation and Antes shale contained in this interval.	40	40
	Thickness of concealed interval		40
COBURN FORMATION			
1.	Calcilutite, argillaceous, grayish black, with numerous interlayers of laminated and cross-laminated, fine-grained calcarenite (30%), as well as a few bands of crinoidal calcarenite. Beds are 2 to 10 inches thick.	4	18
2.	Calcarenite, mostly crinoidal, in 2- to 6-inch beds.	1	14
3.	Calcilutite, argillaceous, in 2- to 4-inch beds, with numerous shale interlayers.	2	13
4.	Calcarenite, abundantly laminated and cross-laminated, fine-grained, in 4- to 6-inch beds, with numerous interlayers of calcareous shale. Some calcarenite layers are crinoidal.	11	11
	Exposed thickness of Coburn Formation		18
SALONA FORMATION			
Roaring Spring Member			
5.	Concealed.	44	260½
6.	Calcilutite, argillaceous, grayish black, with interlayers of abundantly argillaceous calcilutite (10%), mostly near top, as well as several beds of laminated, very-fine-grained calcarenite. Beds commonly 4 to 6 inches thick.	22	216½
7.	Calcilutite, argillaceous, in 2- to 6-inch beds. Most of unit weathered.	15	194½
8.	Calcilutite, abundantly argillaceous, black, in 6-inch to 1-foot beds, with several interlayers of laminated, very-fine-grained calcarenite. *Dalmanella* sp. rare.	15	179½
9.	Calcilutite, argillaceous, partly laminated, grayish black, in 4- to 6-inch, some 1-foot, beds, with interlayers of abundantly argillaceous calcilutite (10%) especially near top. Metabentonite (?), 1 foot thick, about 12 feet above base.	20	164½

10.	Calcilutite, argillaceous, black, in 6-inch beds, with interlayers of laminated, very-fine-grained, calcarenite (10%). Very weathered.	12½	144½
11.	Metabentonite (?), 1 foot thick.	1	132
12.	Calcarenite, laminated in part, very-fine-grained, in 6-inch beds. Mostly weathered.	11	131
13.	Calcilutite, abundantly argillaceous, black, in 6-inch to 1-foot beds, with interlayers of laminated, very-fine-grained calcarenite (10%). *Cryptolithus tesselatus* rare, mostly in lower one-half of unit.	40	120
14.	Metabentonite, yellowish-weathered, 1½ inches thick.		
15.	Calcilutite, argillaceous, black, in 1-foot beds, with several interlayers of laminated, very-fine-grained calcarenite. Base marked by abundantly argillaceous calcilutite, 1½ feet thick, with *Cryptolithus tesselatus*.	11½	80
16.	Metabentonite, yellowish-weathered, 1 inch thick, underlain by 2 inches of cherty limestone.		
17.	Calcilutite, argillaceous, grayish black, in 6-inch to 1-foot beds, with several interlayers of laminated, very-fine-grained calcarenite. *Cryptolithus tesselatus* rare at 12½ feet above base; *Sowerbyella* sp rare.	25	68½
18.	Calcilutite, argillaceous, grayish black, in 4- to 6-inch beds. About 30% concealed. This unit is regarded as a tongue of the New Enterprise Member.	19	43½
19.	Concealed.	12	24½
20.	Calcilutite, argillaceous, grayish black, with several interlayers of laminated, fine-grained calcarenite as well as abundantly argillaceous calcilutite. Beds 1 to 6 inches thick.	12	12½
21.	Metabentonite, yellowish-weathered, 6 inches thick.	½	½
	Exposed thickness of Roaring Spring Member		246½
New Enterprise Member			
22.	Calcilutite, argillaceous, grayish black, in 2- to 4-inch beds. *Homalonotus trentonensis* and *Sowerbyella* sp. rare.	5	115
23.	Mostly concealed. Calcilutite, argillaceous, grayish black. *Cryptolithus tesselatus* and *Isotelus* sp. rare.	70	110
24.	Calcilutite, argillaceous, grayish black, in 1-foot beds with 10 to 20 percent of crinoid plates. Mostly concealed.	40	40
	Exposed thickness of New Enterprise Member		115
	Exposed thickness of Salona Formation		375½

WILLOW HILL SECTION

(No. 18)

The Willow Hill section is located in the Orbisonia, Pennsylvania, quadrangle, about 11,500 feet south of 40° 10′ latitude and about 5,000 feet west of 77° 45′ longitude. The exposure is located about three-fourths of a mile southeast of the village of Spring Run along the eastern side of Route 433. At this locality, most of the New Enterprise Member is well exposed and some of the Roaring Spring Member is poorly exposed.

Unit	*Lithologic description*	*Thickness Feet Unit*	*Thickness Feet Total*
	TRENTON GROUP		
	SALONA FORMATION		
	Roaring Spring Member		
1.	Mostly concealed with scattered patches of calcareous shale on slope. This may be the lower part of the Martinsburg formation.	85	130
2.	Calcareous shale, black, with numerous 6-inch interlayers of argillaceous calcilutite and laminated, fine-grained calcarenite in lower part. Mostly concealed.	45	45
	Exposed thickness of Roaring Spring Member		130
	New Enterprise Member		
3.	Calcilutite, abundantly argillaceous, black, with interlayers of calcareous shale.	46	95½
4.	Calcilutite, argillaceous, very dark gray, in 1- to 3-inch beds separated by ½-inch interlayers of shale. Abundantly argillaceous calcilutite, 5 feet thick, at 6 feet to 11 feet below the top. Upper contact of this unit is very sharp.	23	49½
5.	Calcilutite, abundantly argillaceous, black, in 6-inch to 1-foot beds, with several interlayers of argillaceous calcilutite.	7	26½
6.	Metabentonite No. 5, yellowish-weathered, 6 inches thick.	½	19½
7.	Calcilutite, abundantly argillaceous, black, in 2-foot beds at base, with numerous 6-inch interlayers of argillaceous calcilutite in upper part. Upper bed, 10 inches thick.	9	19
8.	Metabentonite No. 4, yellowish-weathered, 3 inches thick.		
9.	Calcilutite, argillaceous, black, and alternating with abundantly argillaceous calcilutite, both in 1- to 3-inch beds.	3	10
10.	Metabentonite No. 3, 1 inch thick.		
11.	Calcilutite, abundantly argillaceous, black, in 6-inch beds with a 3-foot bed at base, with several 1-inch interlayers		

	of limestone in upper part. Lower 3 feet are strongly cleaved.	4½	7
12.	Metabentonite Nos. 1 and 2, 6 inches thick.	½	2½
13.	Calcilutite, argillaceous, black, in 6-inch beds, with few crinoid plates.	2	2
	Thickness of New Enterprise Member		95½
	Exposed thickness of Salona Formation		225½
	ORANDA FORMATION		
	Calcilutite, medium dark gray, in 1- to 3-inch beds with numerous crinoid plates and a 4-inch interlayer of crinoidal calcarenite at 4 feet above base.	5½	16½
	Metabentonite No. 0, 2 inches thick.		
	Calcilutite, medium dark gray, in 1- to 3-inch beds with numerous brachiopods, crinoids and sponges. Black chert nodules, 1½ inches in maximum diameter, at 1½ to 2½ feet below top.	11	11
	Measured thickness of Oranda Formation		16½

FORT LOUDON SECTION

(No. 19)

The Fort Loudon section is located in the Mercersburg, Pennsylvania, quadrangle, about 3,250 feet south of 39° 55′ latitude, and about 2,750 feet east of 77° 55′ longitude. The exposure is located about one-half mile south of Fort Loudon along the western bank of the West Branch of Conococheague Creek. At this locality, the calcarenites and bioskeletal calcirudites that respectively characterize the Roaring Spring Member and the Coburn Formation are absent, and the entire sequence consists of argillaceous limestones and calcareous shales which are considered by Craig (1949) to comprise the lower part of the Martinsburg formation. The metabentonites described below are numbered solely on the basis of their stratigraphic spacings in relationship to the spacings of metabentonites at other localities.

Unit	*Lithologic description*	*Thickness* *Feet* *Unit*	*Total*
	MARTINSBURG FORMATION		
1.	Argillaceous limestone and calcareous shale.	90	250½
2.	Metabentonite (?), 2 to 3 inches thick.		
3.	Calcilutite, abundantly argillaceous, black, in 4- to 6-inch beds. Mostly concealed.	25	160½

4.	Metabentonite, 3 to 4 inches thick.		
5.	Calcareous shale, black, with interlayers of abundantly argillaceous calcilutite. Partly concealed.	30	135½
6.	Calcilutite, abundantly argillaceous, and calcareous shale, with several interbeds of argillaceous calcilutite. Much concealed.	19	105½
7.	Metabentonite, 2 inches thick.		
8.	Calcilutite, abundantly argillaceous.	3	86½
9.	Metabentonite, 6 to 8 inches thick.	½	83½
10.	Calcilutite, abundantly argillaceous, black, in 4- to 6-inch beds, with several interbeds of argillaceous calcilutite. Partly covered.	28	83
11.	Metabentonite No. 5 (?), 2 inches thick.		
12.	Calcilutite, abundantly argillaceous, black, in 3- to 8-inch beds, with calcareous shale.	45	55
13.	Calcilutite, abundantly argillaceous, black, in 4- to 6-inch beds.	10	10
	Exposed thickness of Martinsburg Formation		250½

PLATES

PLATE 1. ACID-ETCHED SECTIONS OF BIOSKELETAL CALCIRUDITE.

All 3X magnification. Sections are cut perpendicular to bedding surfaces and are oriented with top of section toward top of plate.

Figure 1. *Sowerbyella* bioskeletal calcirudite with numerous gastropods, showing calcitic fossils deeply etched into residual, tan-colored argillaceous material, which stands in relief. Sample contains 30.5 percent of insoluble residue. Milesburg Member at Bellefonte, 3 feet above base of exposure.

Figure 2. *Sowerbyella* bioskeletal calcirudite showing deeply etched calcitic fossils in a matrix of argillaceous material and intermixed microcryptocrystalline quartz. White object in right center is a silicified bryozoan. Milesburg Member at Roaring Spring, 84 feet above base.

Figure 3. *Sowerbyella*-trilobite bioskeletal calcirudite with light-colored clay standing in relief. Darker part is calcitic. Sample contains about 12.0 percent of insoluble residue. Milesburg Member at Bellefonte, 72 feet above base of exposure.

Figure 4. *Sowerbyella* bioskeletal calcirudite composed mostly of large, unfragmented brachiopods which are aligned parallel to bedding. Tan-colored argillaceous material stands in relief. White objects are silicified fossil parts. Sample contains 5.6 percent of insoluble residue. Milesburg Member at Roaring Spring, about 55 feet above base.

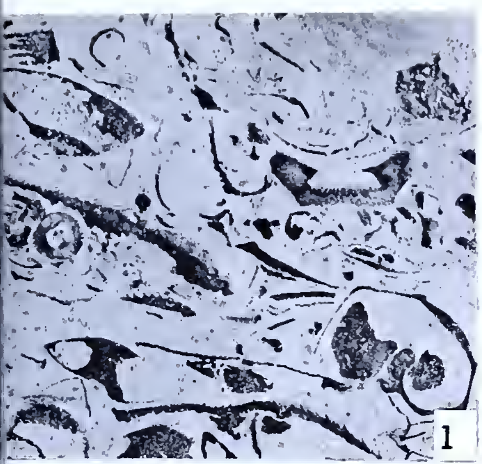
Figure 5. *Sowerbyella* bioskeletal calcirudite similar to Figure 4 but with bryozoan or algal structure in lower middle part. Small white particles scattered on surface are very fine quartz crystals. Milesburg Member at Roaring Spring, about 61½ feet above base.

Figure 6. *Sowerbyella* bioskeletal calcirudite composed mostly of fragmented fossils in a calcitic matrix, with very fine quartz crystals scattered on surface. White quartz replacements of brachiopods and crinoid plates stand in relief. Cavity within large brachiopod is partly replaced by quartz, probably after dolomite, with a rhombohedral outline. Milesburg Member at Roaring Spring, about 37 feet above base.

Figure 7. *Sowerbyella*-trilobite bioskeletal calcirudite showing numerous trilobite fragments and gastropods embedded in a partly argillaceous matrix. Light-colored object in lower left corner is gastropod filled with argillaceous material. Sample contains about 12 percent of insoluble residue. Milesburg Member at Bellefonte, about 21½ feet from top.

Figure 8. *Dalmanella* bioskeletal calcirudite showing local occurrence of chert which encloses fossil fragments. Sample as a whole contains only 6.5 percent of insoluble residue. Coleville Member at Bellefonte, about 98 feet above base.

PLATE 1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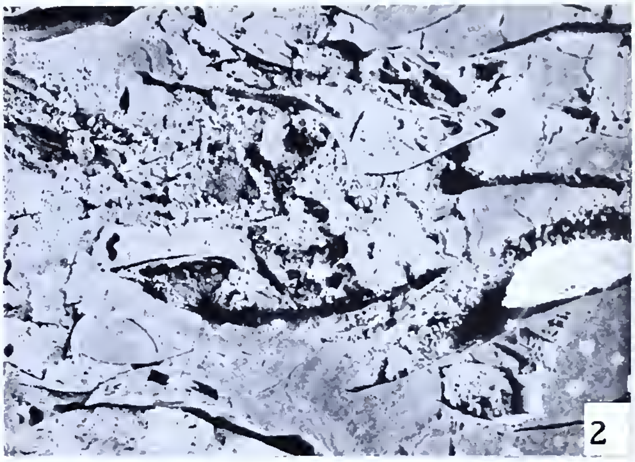
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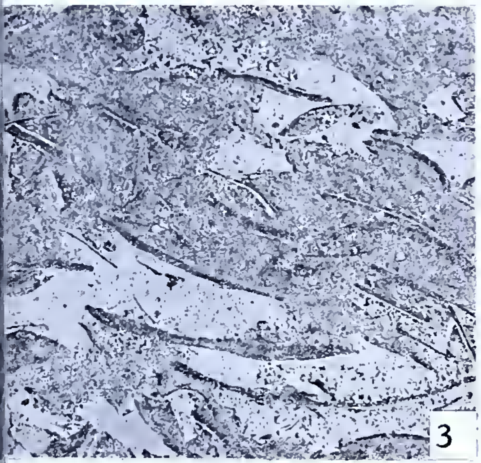
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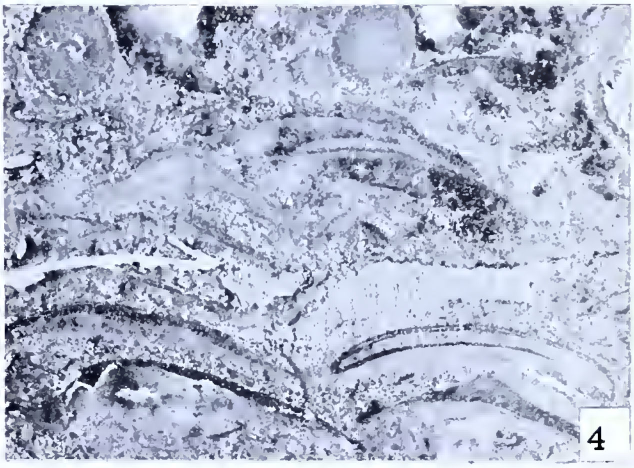
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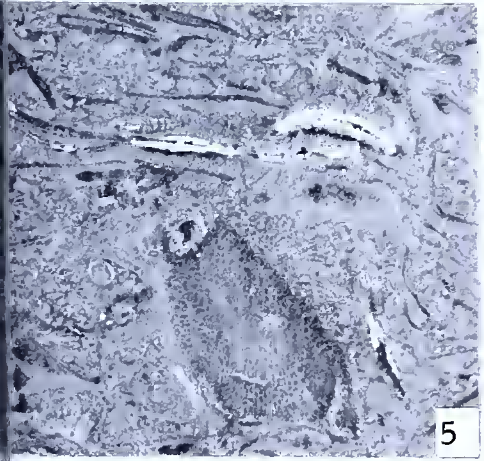
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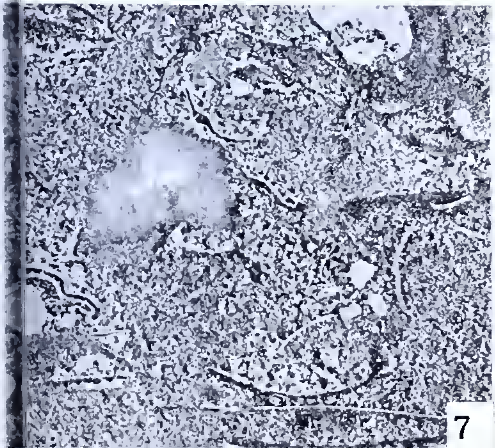
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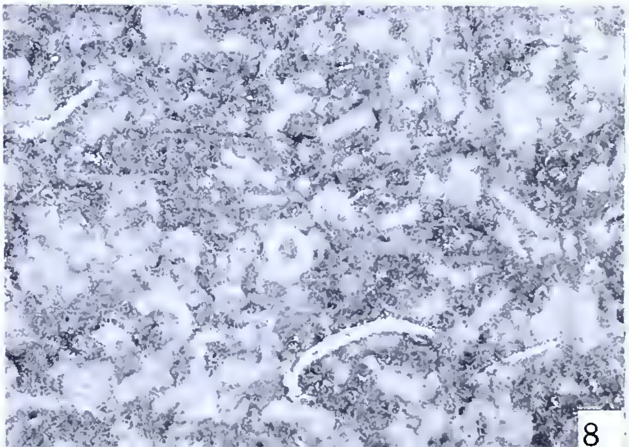
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PLATE 2. ACID-ETCHED SECTIONS OF BIOSKELETAL CALCIRUDITE.

All 3X magnification. Sections are cut perpendicular to bedding surfaces and are oriented with top of section toward top of plate.

Figure 1. Crinoidal bioskeletal calcirudite showing numerous crinoid plates oriented parallel to bedding surface. Lighter-colored residue standing in relief is microcryptocrystalline quartz. Sample contains about 25 percent of insoluble residue. Coleville Member at Bellefonte, about 5 feet above base.

Figure 2. *Dalmanella* bioskeletal calcirudite showing an abundance of fragmented brachiopod valves. Lighter-colored residue standing in relief is argillaceous material. Sample contains about 17.5 percent of insoluble residue. Coleville Member at Bellefonte, about 48 feet above base.

Figure 3. Crinoidal bioskeletal calcarenite abruptly overlying fossiliferous argillaceous calcilutite. Round calcitic pits in calcilutite are worm-burrow-like structures. Sample contains 4.2 percent of insoluble residue. Coleville Member at Bellefonte, about 64 feet above base.

Figure 4. *Sowerbyella* bioskeletal calcirudite abruptly overlying siliceous calcilutite. Irregular shape of contact suggests slumpage while sediment was unconsolidated. Fossils in calcirudite are greatly fragmented. White silicified parts of fossils stand in relief. Milesburg Member at Roaring Spring, about 75 feet above base.

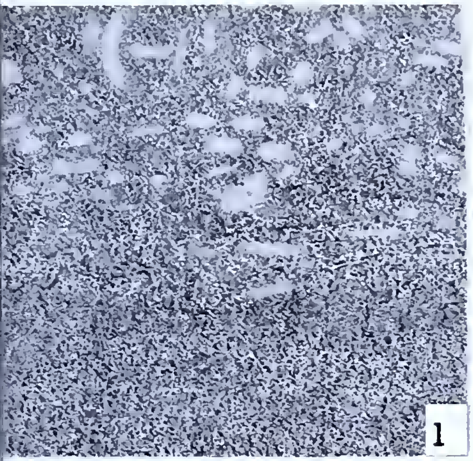
Figure 5. Crinoidal-*Dalmanella* bioskeletal calcirudite grading upward into argillaceous calcarenite. Silicified fossil parts and very fine quartz crystals stand in relief on surface of calcirudite. Sample contains 20 percent of insoluble residue. Coleville Member at Roaring Spring, about 23 feet above base.

Figure 6. *Sowerbyella* bioskeletal calcirudite with band of microcryptocrystalline quartz through center. Dark calcitic fossil parts are deeply etched into siliceous band. Many fossil parts are silicified. Milesburg Member at Roaring Spring, about 60 feet above base.

Figure 7. *Sowerbyella* bioskeletal calcirudite. White silicified parts of fossils stand in relief. Milesburg Member at Roaring Spring, about 60 feet above base.

Figure 8. Crinoidal bioskeletal calcirudite, composed mostly of crinoid plates cemented together by sparry calcite. Silicified brachiopods stand in relief. Sample contains about 2.7 percent of insoluble residue. Coleville Member at Bellefonte, about ½ of a foot above base.

PLATE 2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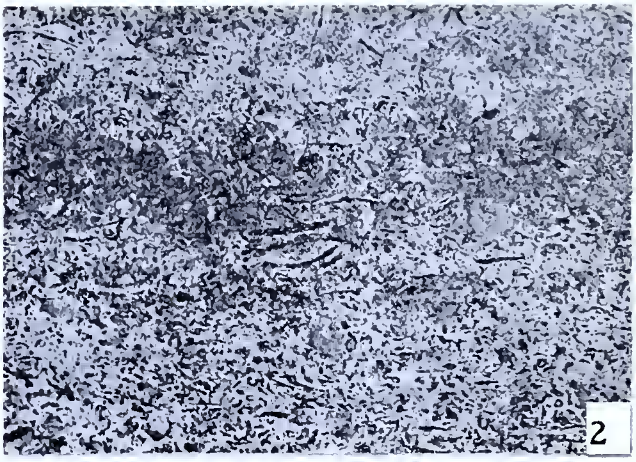
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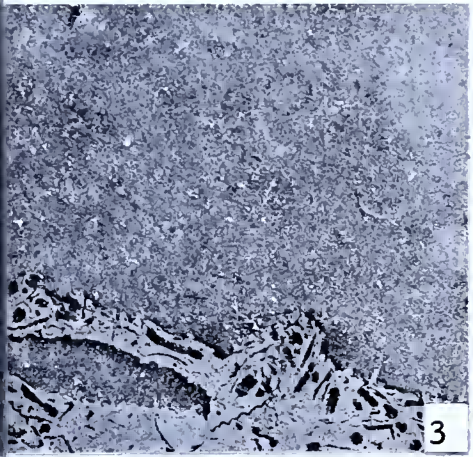
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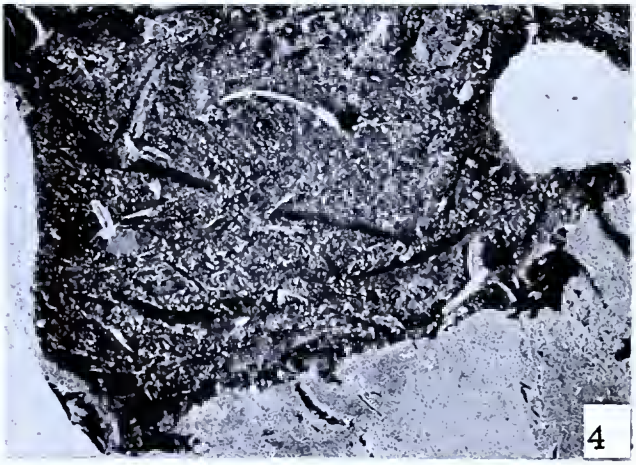
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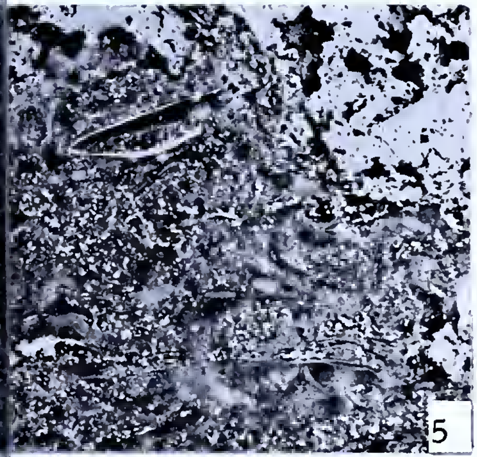
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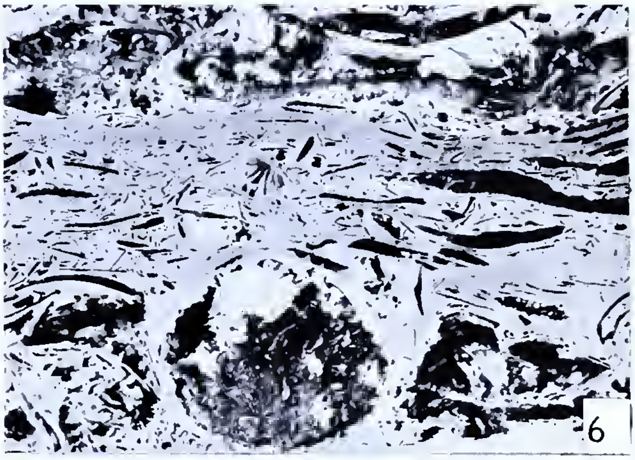
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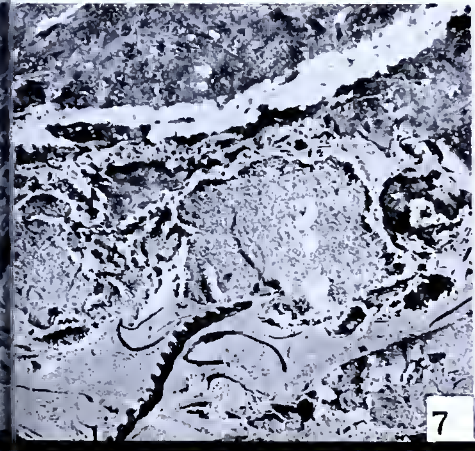
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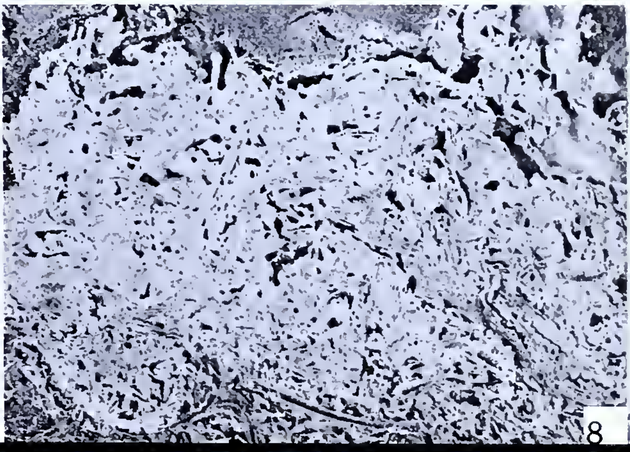
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PLATE 3. PHOTOGRAPHS OF *SOWERBYELLA* AND *DALMANELLA*

Figure 1. *Sowerbyella* sp. Comprises more than 75 percent of the fossils in most of the bioskeletal calcirudites in the Milesburg Member of the Coburn Formation. 1a, 1b, exteriors of pedicle valves, 1a, x4, 1b, x3. 1d, interior of pedicle valve, x3. 1c, 1e, interiors of brachial valves, x4.

Figure 2. *Dalmanella* sp. Comprises more than 75 percent of the fossils in many of the bioskeletal calcirudites in the Coleville Member of the Coburn Formation. 2a, interior of pedicle valve, x4. 2b, interior of brachial valve, x3. 2c, exterior of brachial valve, x4. 2d, exterior of pedicle valve, x4.

PLATE 4. ACID-ETCHED SECTIONS OF CALCARENITES

All 3X magnification. Sections are cut perpendicular to bedding surfaces and are oriented with top of section toward top of plate.

Figure 1. Calcarenite, well laminated, fine-grained. Light-colored laminae are composed of silt-sized crystals of quartz which stand in relief. Burrow at top is filled partly with microcryptocrystalline quartz. Sample contains 9.7 percent of insoluble residue. Coleville Member of the Coburn Formation at Bellefonte, about 80 feet above base.

Figure 2. Calcarenite, fine-grained, with argillaceous laminae near base and pyritic cross-laminae near top. Deeply etched parts are calcitic and contain numerous silt-sized quartz crystals. Roaring Spring Member of Salona Formation at Roaring Spring, about 4 feet above base.

Figure 3. Calcarenite, fine-grained, faintly laminated above contact with underlying siliceous calcilutite. Abundant silt-sized quartz crystals and some pyrite cubes stand in relief on surface of calcarenite. Sample contains 14.5 percent of insoluble residue. Roaring Spring Member of Salona Formation at Roaring Spring, about 26 feet above base.

Figure 4. Calcarenite, fine-grained, with strong white cross-laminae composed of silt-sized quartz. Sample contains about 20 percent of insoluble residue. Coleville Member of the Coburn Formation at Bellefonte, about 31 feet above base.

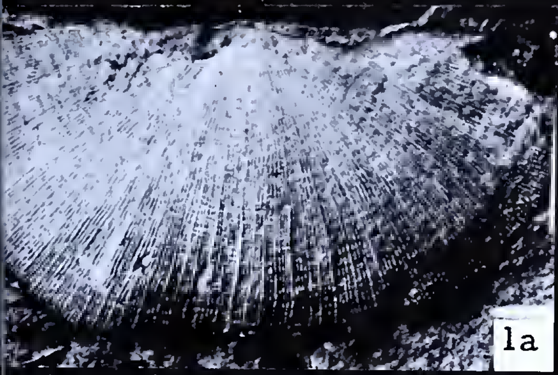
Figure 5. Calcarenite, fine-grained, well laminated. Siliceous in lower two-thirds. Laminae on left side of figure are strongly disturbed. Sample contains 32.5 percent of insoluble residue. Milesburg Member of the Coburn Formation at Bellefonte, about 88 feet above base of exposure.

Figure 6. Calcarenite, fine-grained, well laminated and siliceous. Similar to Figure 5. Sample contains 32.5 percent of insoluble residue. Coleville Member of the Coburn Formation at Bellefonte, about 27 feet above base.

Figure 7. Calcarenite, fine-grained, structureless. Dark part at base is patch of microcryptocrystalline quartz. Sample contains 27.8 percent of insoluble residue. Milesburg Member of Coburn Formation at Bellefonte, about 8 feet above base of exposure.

Figure 8. Calcarenite, fine-grained, structureless. Gray parts, mostly in lower left, are patches of microcryptocrystalline quartz. Roaring Spring Member of Salona Formation at Bellefonte, about 83 feet above base.

PLATE 3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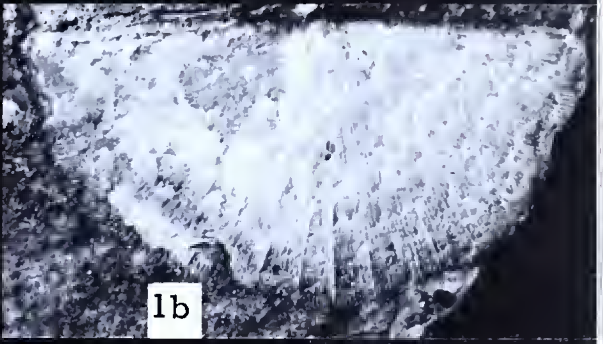
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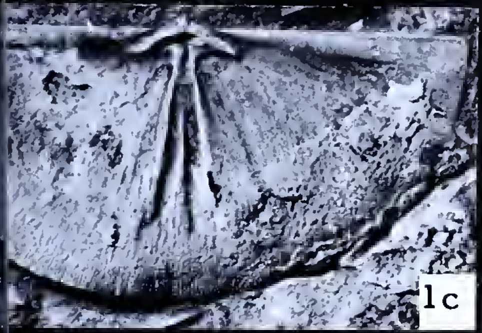
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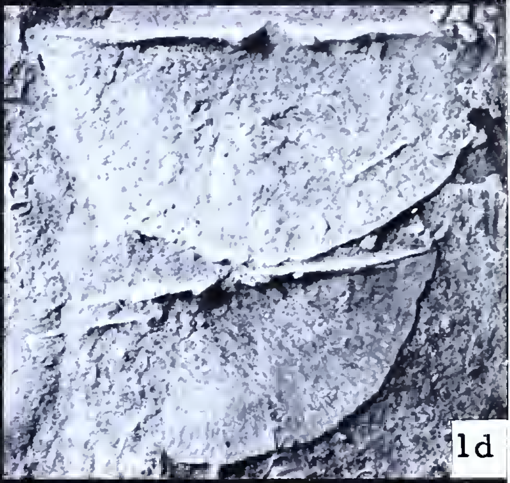
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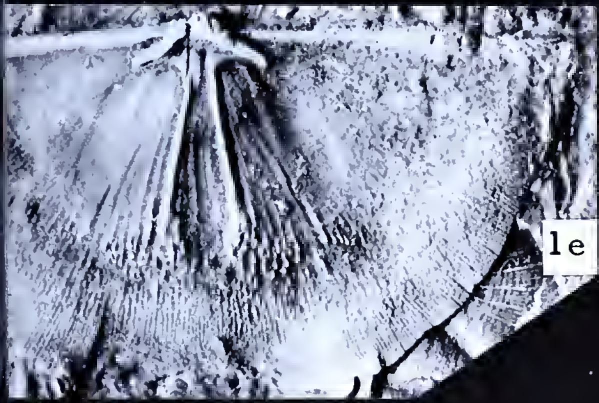
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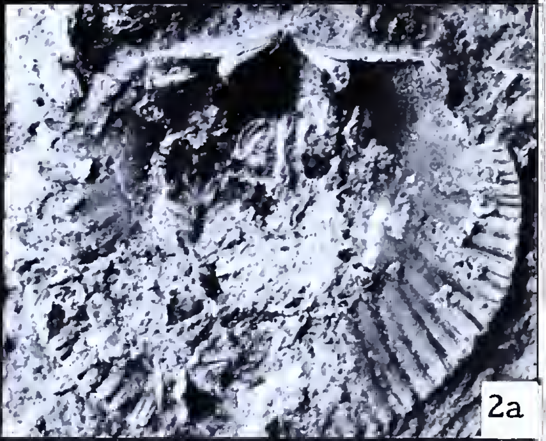
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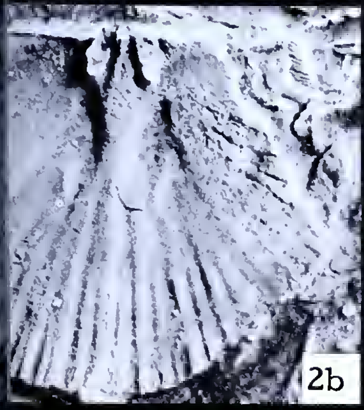
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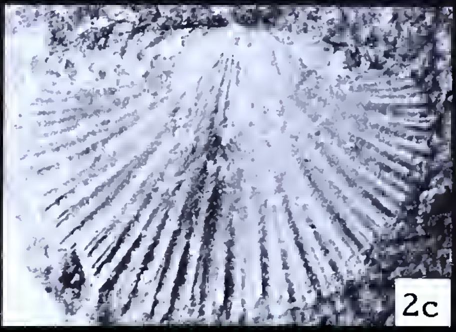
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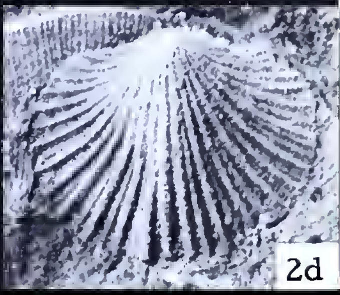
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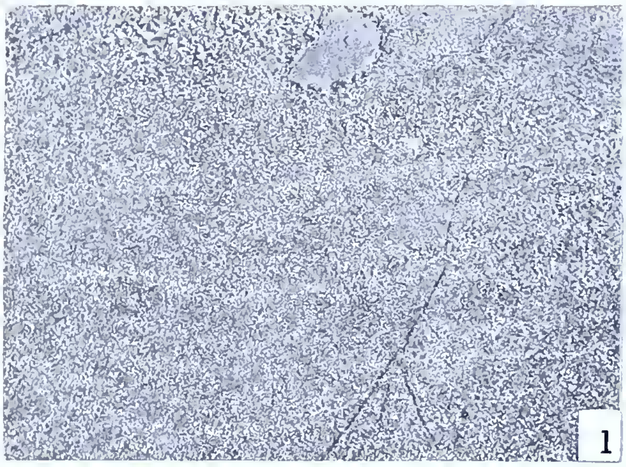
PLATE 4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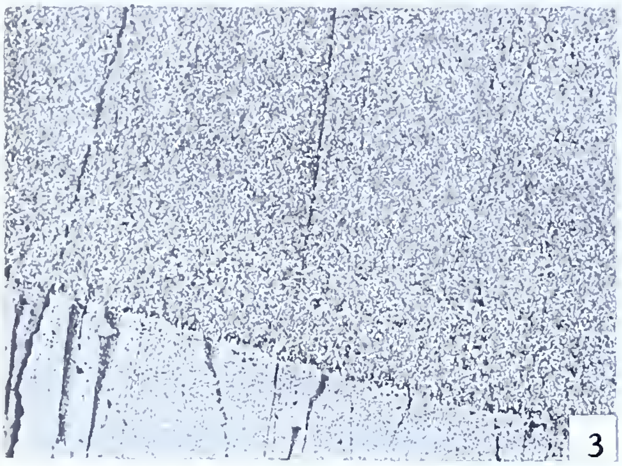
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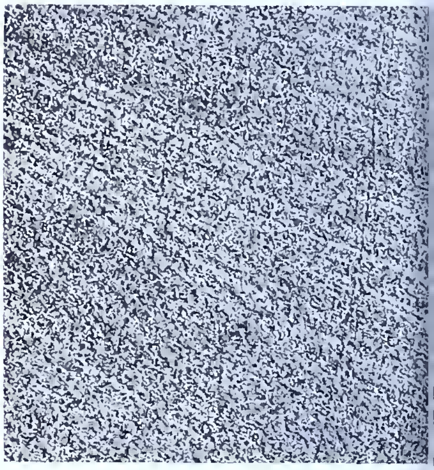

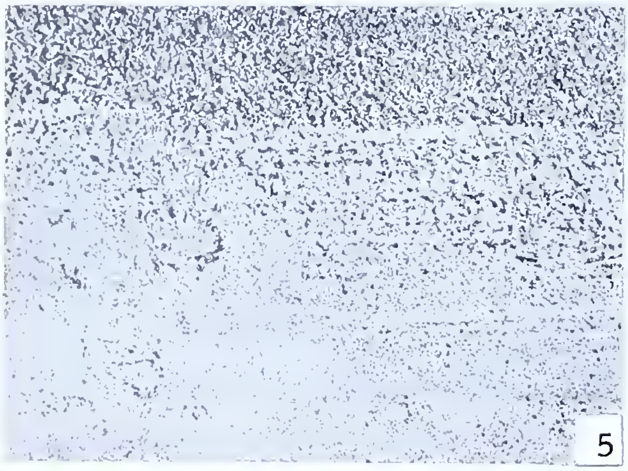
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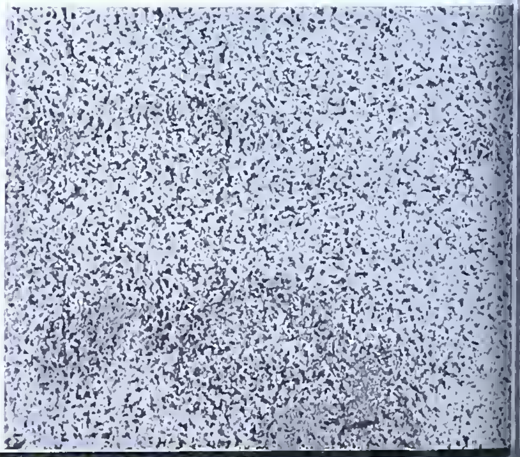
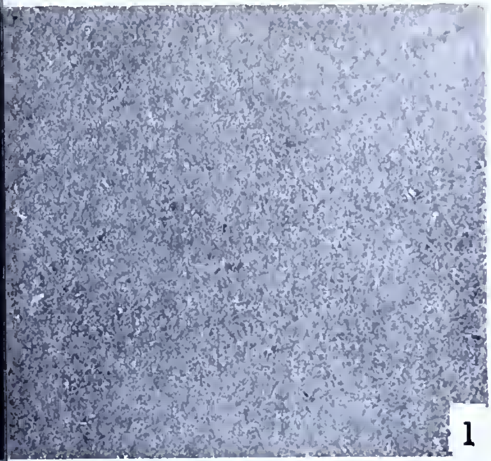


PLATE 5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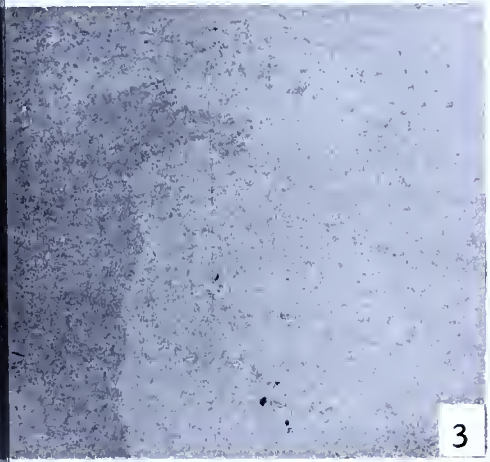
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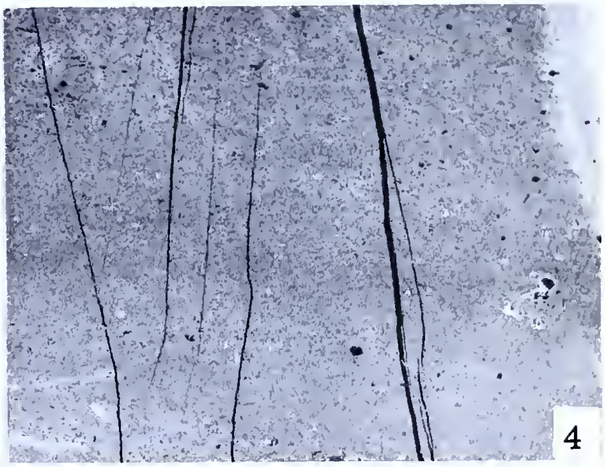
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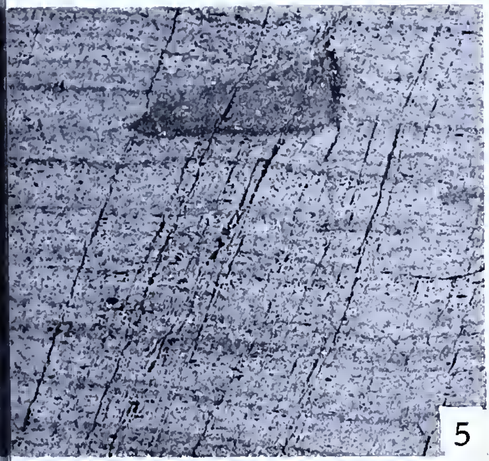
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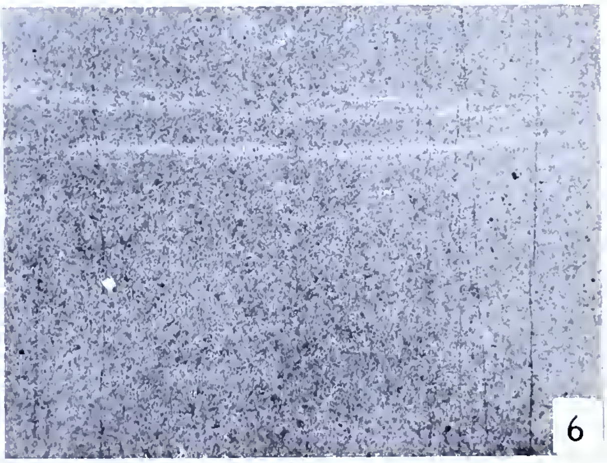
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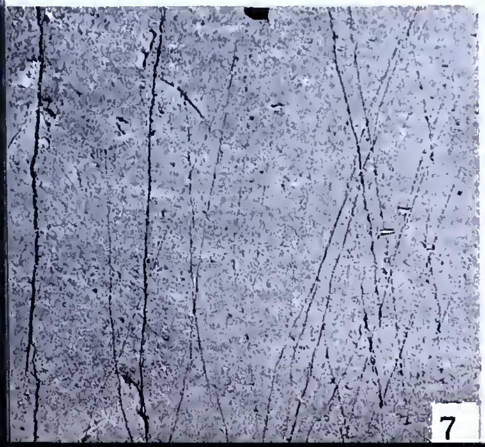
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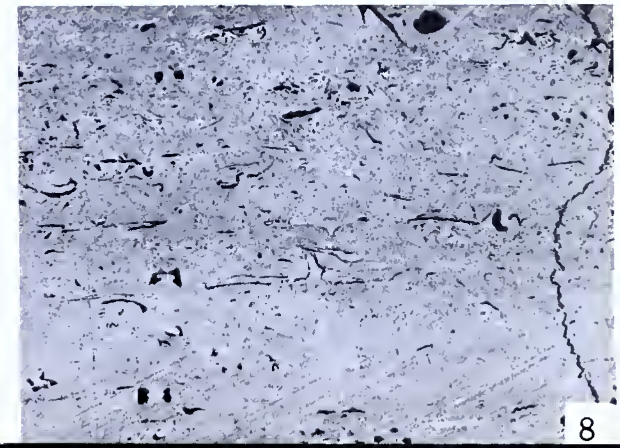
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PLATE 5. ACID-ETCHED SECTIONS OF CALCILUTITES.

All 3X magnification. Sections are cut perpendicular to bedding surfaces and are oriented with top of section toward top of plate.

Figure 1. Calcilutite, structureless, unusually pure containing only 6.5 percent of insoluble residue. Small aggregates of clay stand in relief on surface. New Enterprise Member of Salona Formation at Bellefonte, about 79 feet above base.

Figure 2. Calcilutite, structureless, argillaceous with several deeply etched fragments of calcitic fossils. New Enterprise Member of Salona Formation at Roaring Spring, about 46½ feet above base.

Figure 3. Calcilutite, structureless, siliceous. Except for minute calcitic pit, the entire surface stands in relief. Dark zone at left is partly composed of microcryptocrystalline quartz. Sample contains 47 percent of insoluble residue. Milesburg Member of Coburn Formation at Bellefonte, about 18 feet from top.

Figure 4. Calcilutite, structureless. Surface composed mostly of a network of microcryptocrystalline quartz with scattered pits of deeply-etched calcitic fossils. Light-colored part in upper right corner is weathered zone. New Enterprise Member of Salona Formation at Roaring Spring, about 10 feet above base. Sample taken from cherry limestone immediately below metabentonite clay No. 2.

Figure 5. Calcilutite, strongly laminated. Darker laminae are argillaceous. Fragment included near top of figure. Sample contains 31 percent of insoluble residue. Coleville Member of Coburn Formation at Bellefonte, about 47½ feet above base.

Figure 6. Calcilutite, mostly structureless, with silty laminae in upper part. Sample contains 31 percent of insoluble residue. Roaring Spring Member of Salona Formation at Roaring Spring, about 53 feet above base.

Figure 7. Calcilutite, abundantly argillaceous, showing faint suggestion of bedding. Fragments of calcitic fossils and calcite-filled fractures are etched deeply into argillaceous material which stands in relief. Sample contains 19 percent of insoluble residue. New Enterprise Member of the Salona Formation at Bellefonte, about 1 foot below top.

Figure 8. Calcilutite, abundantly argillaceous, showing abundance of fragments of calcitic fossils which are etched deeply into the argillaceous material which stands in relief. Slight suggestion of bedding. Diagonal marks in lower part are saw cuts. New Enterprise Member of Salona Formation at Roaring Spring, about 9 feet above base.

PLATE 6. THE SALONA FORMATION AT ROARING SPRING

Figure 1. Contact of New Enterprise Member of Salona Formation with underlying Rodman Member of Nealmont Formation. Width of photograph equals about 45 feet. Rodman Member is represented by 12 feet of thick beds to right of photograph, and is overlain fairly abruptly by thinner beds of New Enterprise Member to left. Metabentonites Nos. 0, 1, 2, 3, are labelled above picture and form prominent partings in rock sequence. Numerous shaly partings are visible in sequence between metabentonite No. 1 and base of New Enterprise Member.

Figure 2. Contact of New Enterprise and Roaring Spring Members of Salona Formation. Width of photograph equals about 17 feet. Thin beds of laminated calcarenite of Roaring Spring Member occur in 6 feet at left of photograph and are underlain by thicker calcilutite beds of New Enterprise Member at right. Prominent parting in center of photograph is metabentonite No. 5 (?) as labelled above.

PLATE 6

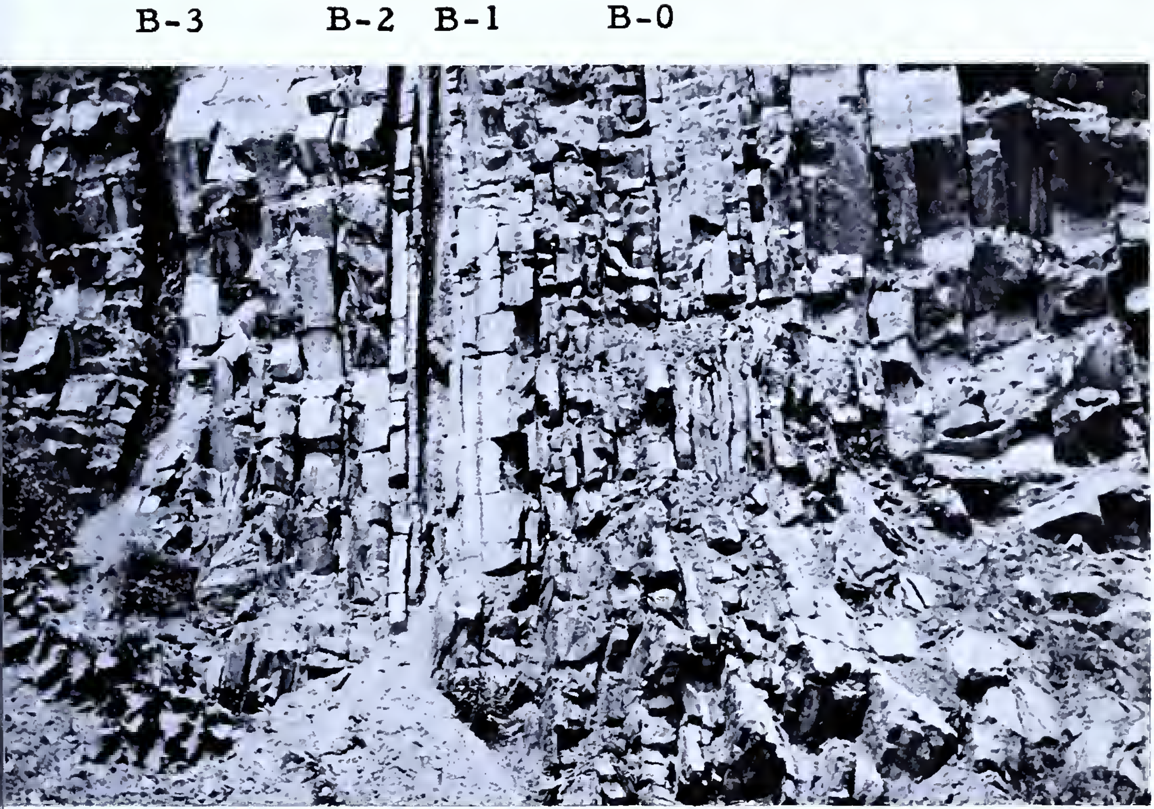

Figure 1

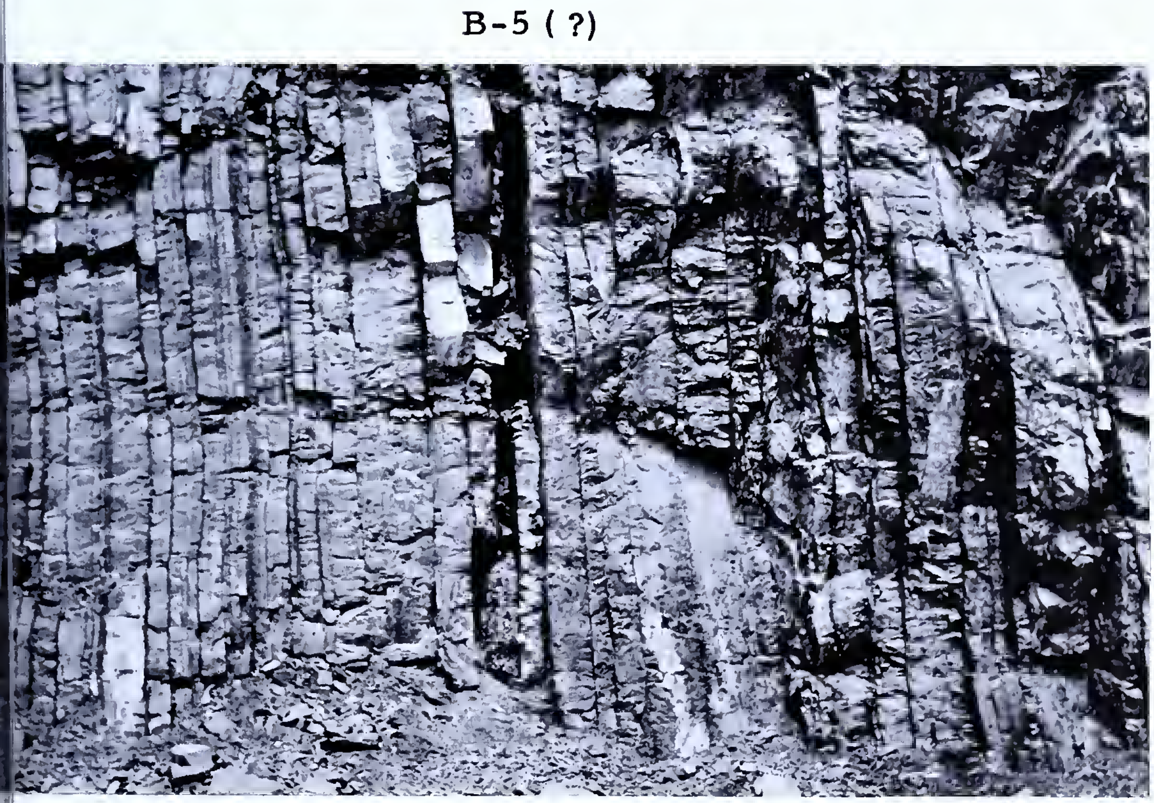

Figure 2

PLATE 7. ACID INSOLUBLE COMPONENTS IN THE LIMESTONES OF THE COBURN AND SALONA FORMATIONS

Figures 5-10 and 12-16 are photomicrographs.

Figure 1. Siliceous aggregates, X 5, angular and extremely resistant, containing impressions of fossil parts. These aggregates have retained the size and shape of the original chips before solution in hydrochloric acid, and are composed in part of microcryptocrystalline quartz.

Figure 2. Argillaceous-siliceous aggregates, X 5, smaller in size and less angular than siliceous aggregates, and generally lacking fossil impressions.

Figure 3. Argillaceous aggregates, X 5, very friable, lacking fossil impressions. Most of these aggregates formed during drying after solution of rock in acid.

Figure 4. Black, brittle, conchoidally-fracturing organic (?) particles, X 5.

Figure 5. Silicified ostracode shell, X 60, forming multicrystalline chert plate which contains numerous larger quartz crystals.

Figure 6. Quartz after calcite or dolomite, retaining rhombohedral shape and cleavage partings, X 40.

Figure 7. Chert plate, X 60, similar to Figure 5 but without larger quartz crystals.

Figure 8. Silicified bryozoan, X 75, composed of massive quartz that apparently contains an abundance of organic matter.

Figure 9. Silicified bryozoan, X 125. Enlargement of Figure 8.

Figure 10. Crystals of apatite, X 140, showing inclusion elongate in direction of C axis. From metabentonite No. 4 at Roaring Spring.

Figure 11. Massive, irregular quartz, X 9, apparently from a cavity-filling or from replacement of central part of crinoid stem plate.

Figure 12. Zoned and twinned crystal of feldspar, X 90, characteristic of heavy mineral suite from metabentonite No. 3 at Roaring Spring.

Figure 13. Chert plate, X 100, enlargement of Figure 7. Apparently is replacement of outer part of trilobite shell.

Figure 14. Crystals of quartz (Q) and feldspar (F), X 100, in an insoluble residue. Dark coverings are coatings of clay, not inclusions.

Figure 15. Heavy mineral residue, X 50, from metabentonite No. 7 at Roaring Spring, showing apatite (A), biotite mica (B) and zircon (Z), all fairly well worn.

Figure 16. Heavy mineral residue, X 50, from metabentonite No. 4 at Roaring Spring, showing an abundance of biotite flakes (B) and well-formed crystals of apatite (A) and zircon (Z).

PLATE 7

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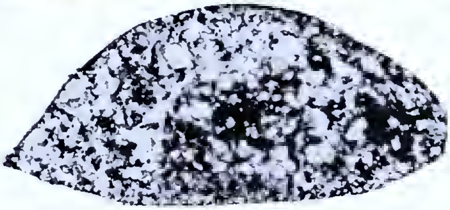
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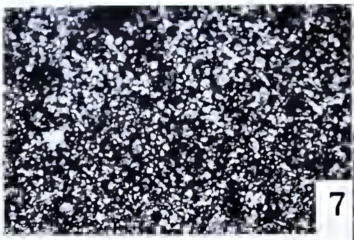
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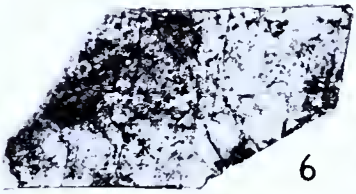
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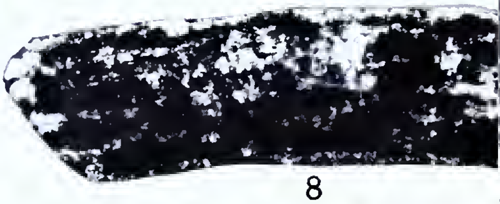
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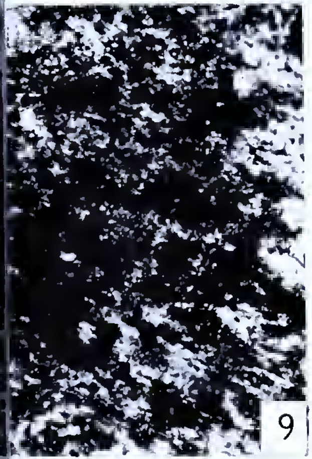
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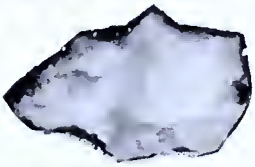
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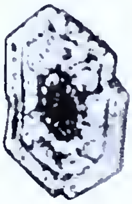
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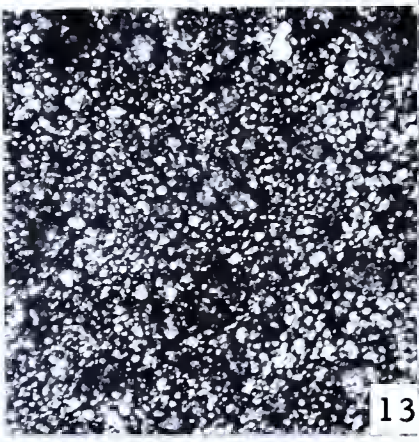
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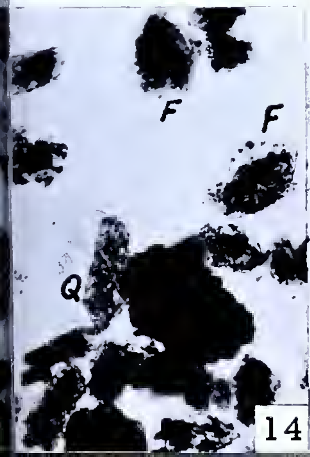

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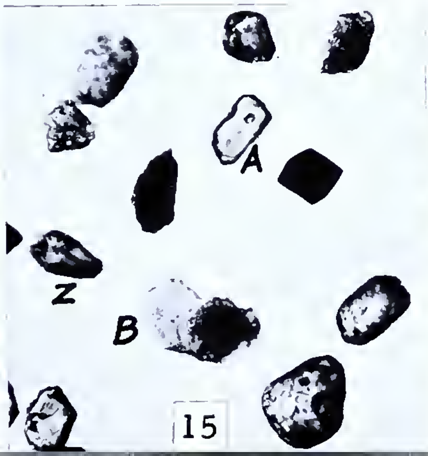

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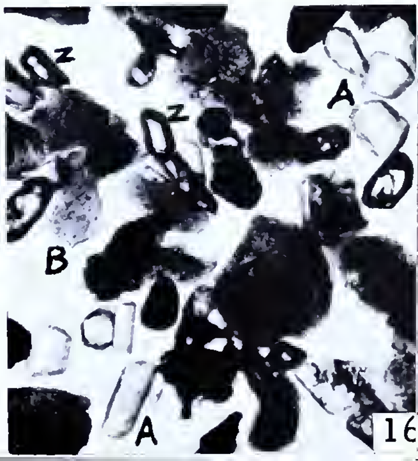

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PLATE 8. PHOTOMICROGRAPHS OF BIOSKELETAL CALCIRUDITES AND CALCARENITES.

Thin sections are cut perpendicular to bedding and are oriented with top of section toward top of plate.

Figure 1. Bioskeletal calcirudite, X 32, showing grains of fossils, pellets and quartz crystals cemented by megasparry calcite. Fibrous fossil parts are brachiopods. Calcite overgrowths on crinoid plates occur in upper left and upper right. Pellets are small, dark, rounded objects and quartz crystals are small, white, elongate crystals. Milesburg Member at Roaring Spring, about 75 feet above base. Etched specimen of same sample pictured in Plate 2, Figure 4.

Figure 2. Bioskeletal calcirudite, X 32, showing fossil grains embedded in a matrix of microcrystalline calcite. Cavity under fibrous brachiopod shell, now filled with megasparry calcite, apparently formed in protected space at time of deposition and aids in identifying upward direction. Black specks are pyrite cubes. Numerous calcite-filled fractures oriented vertically in picture. Milesburg Member at Roaring Spring, about 60 feet above base. Etched section of same sample pictured in Plate 2, Figure 6.

Figure 3. Bioskeletal calcirudite, X 32, showing fossils embedded in a matrix of microcrystalline calcite. Light-colored patches in matrix are crystals of quartz, whereas dark-colored pellets are few. Outer margins of three structureless trilobites in center of picture are replaced by chert which appears as plates in insoluble residues. Notice unbroken condition of trilobites. Milesburg Member at Bellefonte, about 3 feet above base of exposure. Etched section of same sample pictured in Plate 1, Figure 1.

Figure 4. Bioskeletal calcirudite, X 32, showing fossils embedded in a matrix composed of grains of pellets and crystals of quartz cemented by microsparry calcite. Milesburg Member at Roaring Spring, about 37 feet above base. Etched section pictured in Plate 1, Figure 6.

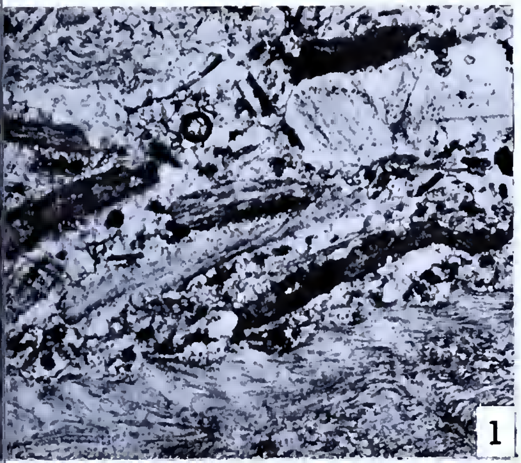
Figure 5. Calcarenite, X 60, showing abundance of dark, ovate to elongate pellets, white crystals of quartz, and a few fossil specimens cemented by microsparry calcite. Note several light gray pellets which appear to be replaced by microsparry calcite. Quartz crystals do not penetrate pellets. Milesburg Member at Roaring Spring, about 15 feet below top. Sample contains 20.2 percent of insoluble residue, mostly owing to quartz crystals.

Figure 6. Calcarenite, X 60, showing grains of gray pellets, partly replaced by microsparry calcite, and few quartz crystals, both cemented by microsparry calcite. Milesburg Member at Roaring Spring, about 23 feet above base.

Figure 7. Calcarenite, X 100, showing hazy, dark gray pellets and white crystals of quartz and feldspar with an abundance of interstitial microcrystalline calcite as well as microsparry calcite cement. Even at this magnification, crystals of quartz and feldspar do not appear to penetrate pellets. Milesburg Member at Bellefonte, about 8 feet above base of exposure. Etched section pictured in Plate 4, Figure 7.

Figure 8. Calcarenite, X 32, separated from underlying calcilutite by an abrupt, irregular scour contact. Calcarenite includes rounded fragments of calcilutite-like material as well as grains of pellets and crystals of quartz and feldspar. Quartz and feldspar, white patches, are especially abundant just above irregular contact, but decrease upward in part of thin section not pictured. Faint black pellets can be seen in upper part of calcilutite as well as in calcilutite-like fragments. Milesburg Member at Roaring Spring, about 32 feet below top.

PLATE 8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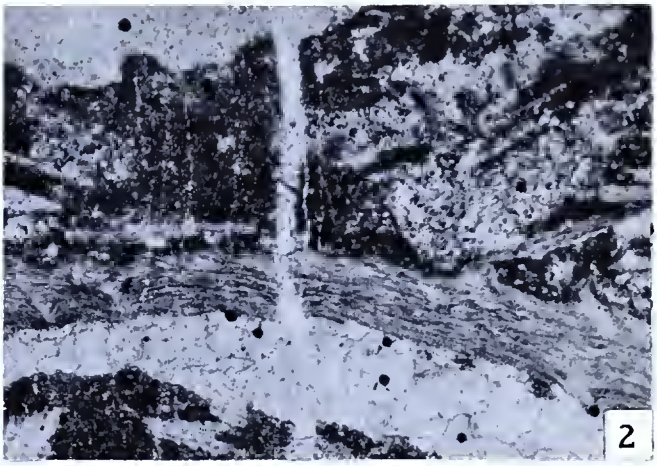
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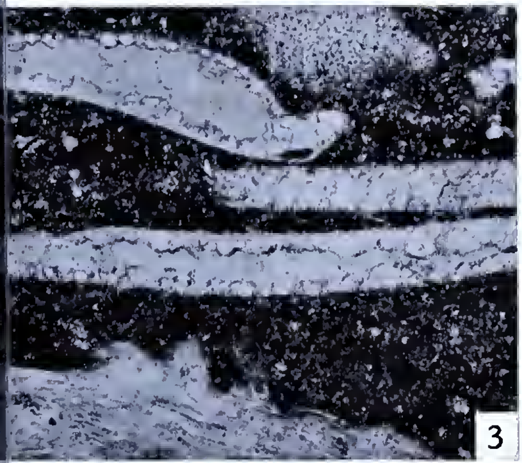
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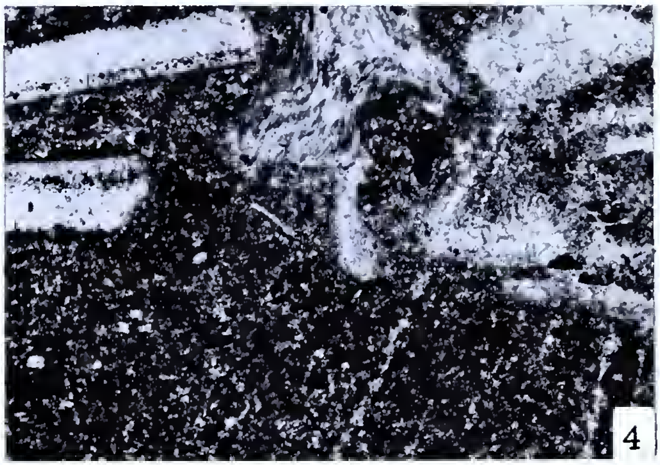
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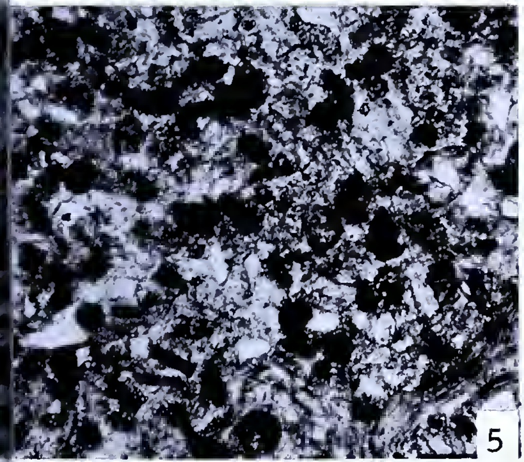
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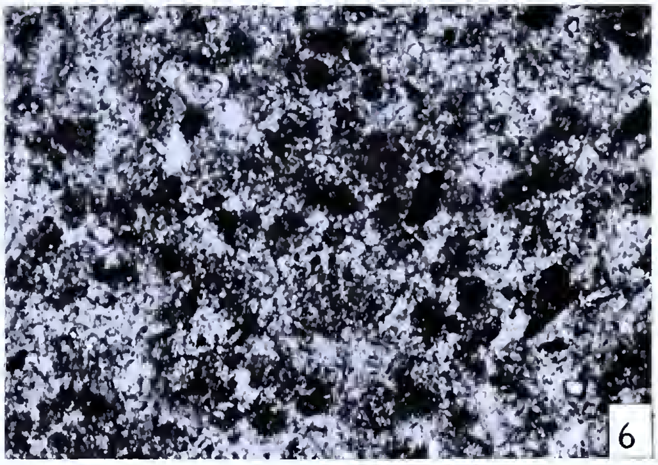
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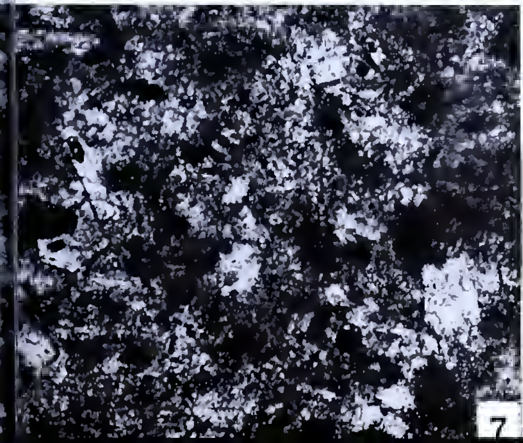
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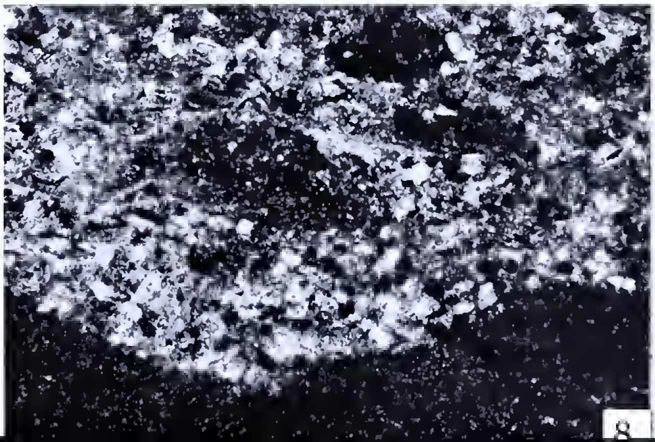
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PLATE 9. PHOTOMICROGRAPHS OF CALCARENITES, CALCILUTITES, AND DOLOMITIC LIMESTONES.

Thin sections are cut perpendicular to bedding and are oriented with top of section toward top of plate.

Figure 1. Calcarenite, X 100, abruptly overlying calcilutite. Dark gray pellets in calcarenite are poorly defined and perhaps partly replaced by microsparry calcite. Poorly oriented white crystals of quartz and feldspar are abundant. Small black pellets are faintly visible in calcilutite. New Enterprise Member at Roaring Spring, about 22 feet above base.

Figure 2. Calcilutite, argillaceous, X 60, showing calcite in patches and separate crystals scattered through mass of argillaceous material and microcrystalline calcite. Visible calcite crystals might represent recrystallization of lime mud. No grains are visible and the rock appears to be structureless. Rock contains about 10 percent of clayey insoluble residue. Coleville Member at Bellefonte, about 133 feet above base.

Figure 3. Calcilutite, abundantly argillaceous, X 32, with irregular, nearly black, clayey laminae in matrix of coarser microcrystalline calcite. Numerous white quartz crystals and a few fossil parts in basal one-third of slide. Rock contains microcryptocrystalline quartz and about 32 percent of insoluble residue. Coleville Member at Bellefonte, about 26 feet above base.

Figure 4. Calcilutite, abundantly argillaceous, X 100, showing abundance of fossil debris in microcrystalline calcite. Large fossil part in center of photograph is a crinoid plate. Opaque parts probably are clay, presumably colored by organic matter. Sample contains about 18.5 percent of insoluble residue. New Enterprise Member at Bellefonte, about 75 feet above base.

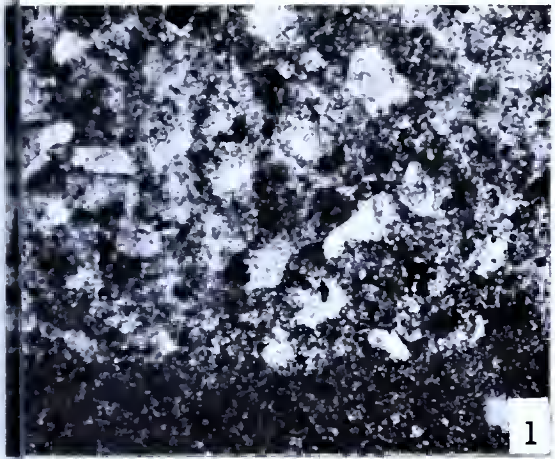
Figure 5. Calcilutite, argillaceous, X 32, with a lighter-colored burrow in center of field. Generally, the burrows contain an appreciable portion of organic matter and are darker than the surrounding matrix. Notice faint concentric appearance of interior and exterior of burrow. Sample contains about 9.5 percent of insoluble residue. New Enterprise Member at Bellefonte, about 14 feet above base. Etched section pictured in Plate 10, Figure 2.

Figure 6. Bioskeletal calcirudite, X 60, showing idiomorphic dolomite in a matrix of lime mud. The dolomite does not penetrate the fossil fragments. Black particles in fibrous brachiopod shells are pyrite. Milesburg Member at Roaring Spring, about 53 feet above base.

Figure 7. Dolomitic limestone, X 60, showing bands of xenomorphic dolomite separated by a clayey lamina. Dolomite in upper band is more abundant and coarser than dolomite in lower band. In detail, each dolomite crystal is separated from others by a thin thread of organically-colored clay. Roaring Spring Member at Reedsville, about 71 feet above base.

Figure 8. Calcilutite, sparingly argillaceous, X 32, showing included, typically dark-colored burrow that is dolomitized in central portion. Much of the remainder of burrow is filled by microcryptocrystalline quartz. Milesburg Member at Roaring Spring, about 11 feet above base. Etched section pictured in Plate 10, Figure 1.

PLATE 9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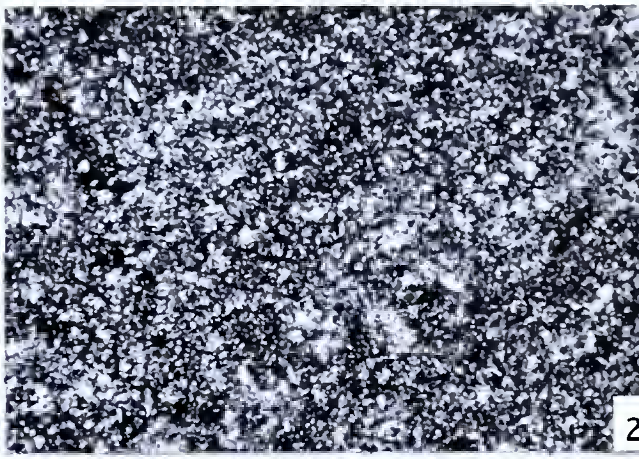
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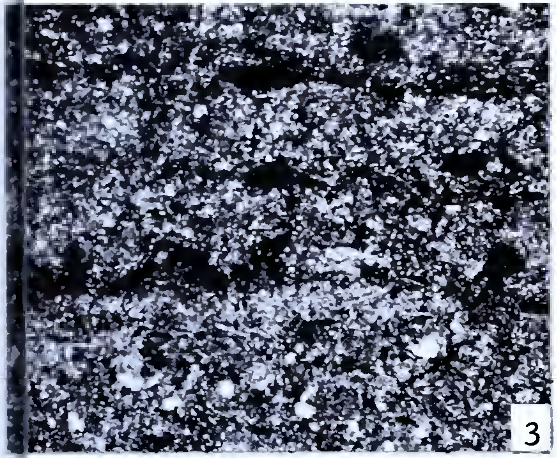
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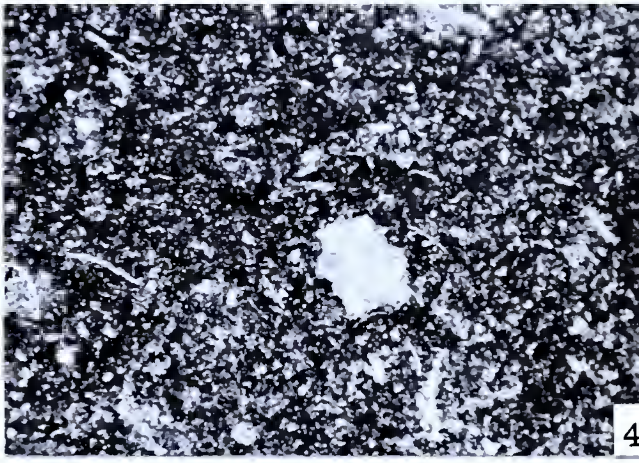
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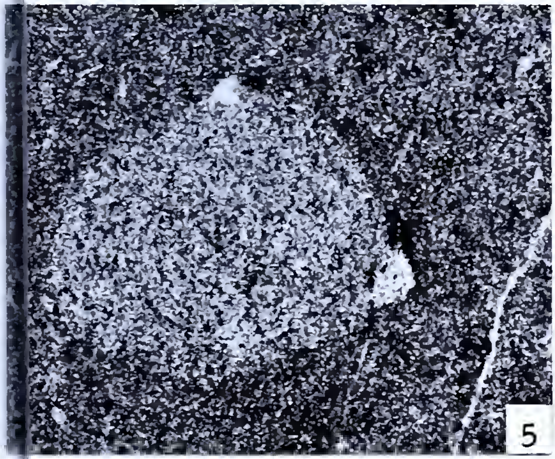
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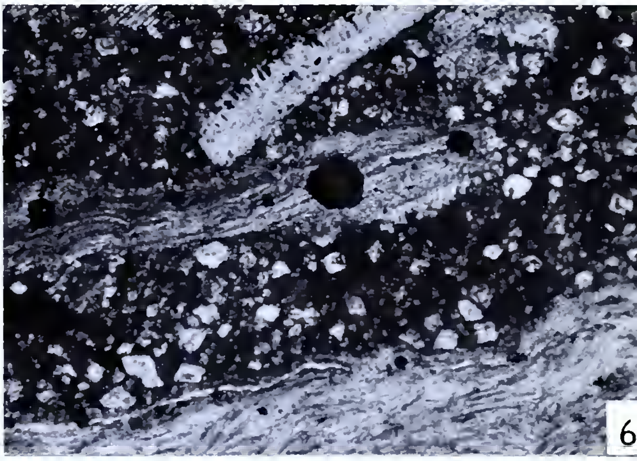
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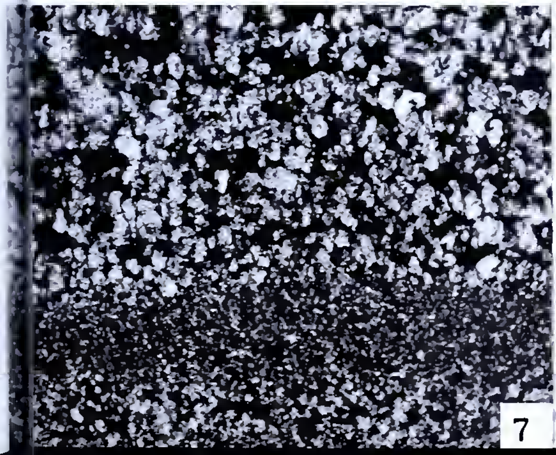
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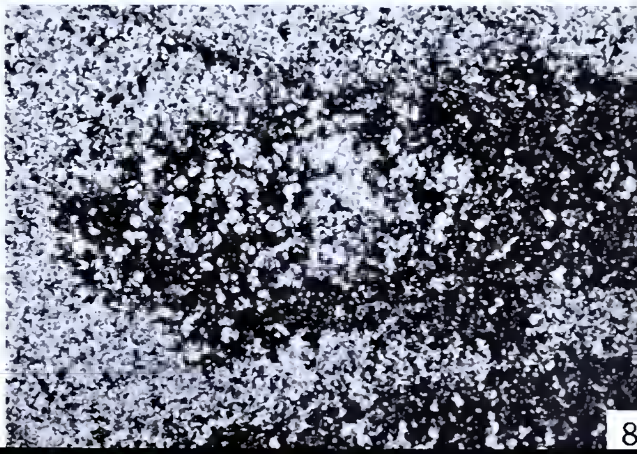
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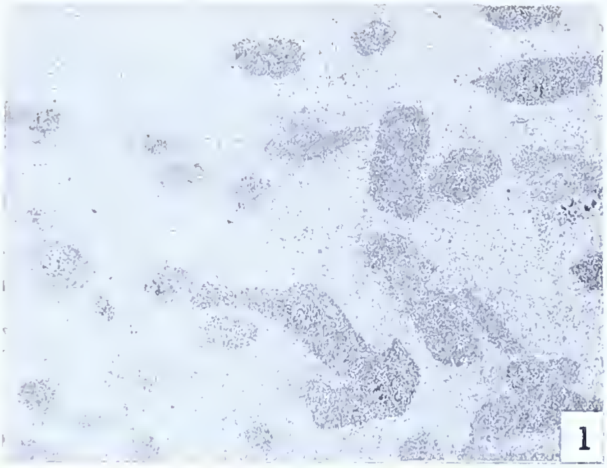
PLATE 10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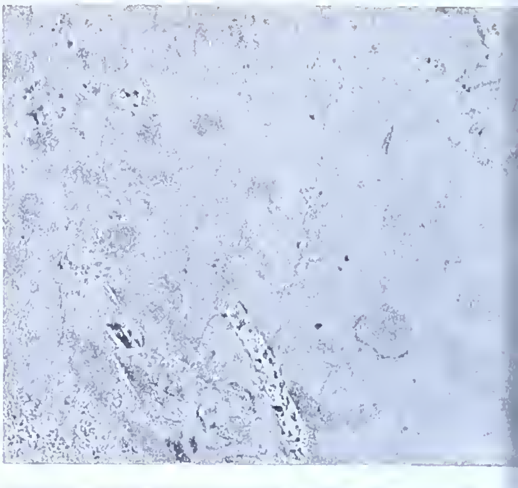

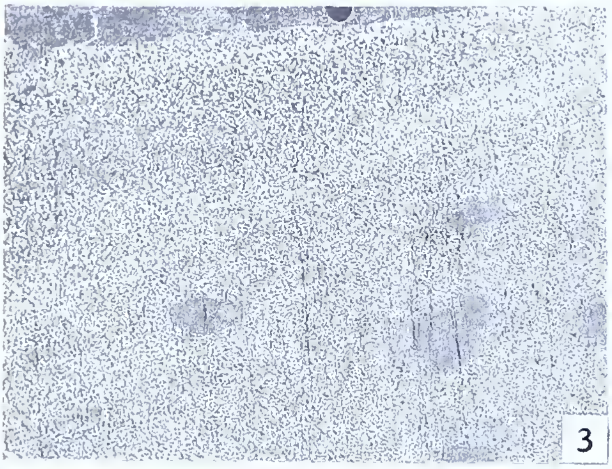
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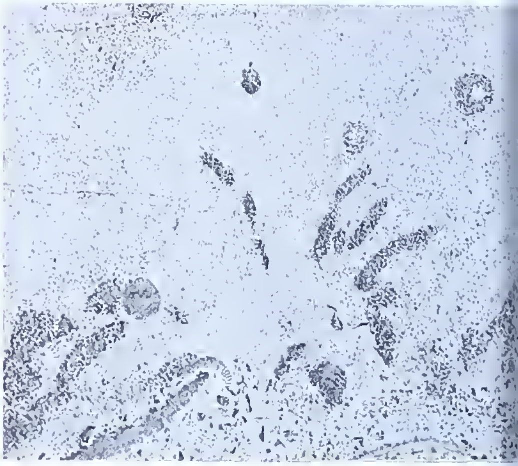

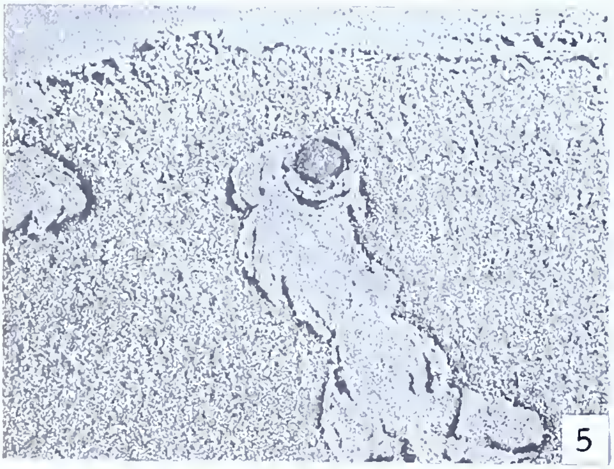
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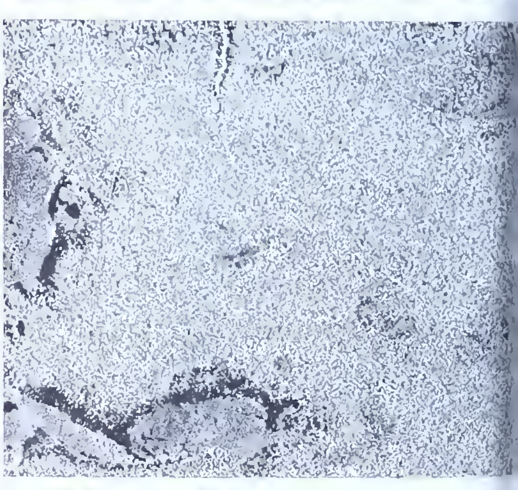

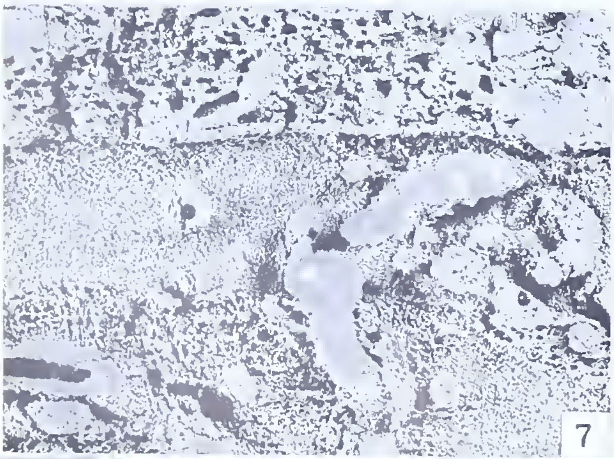
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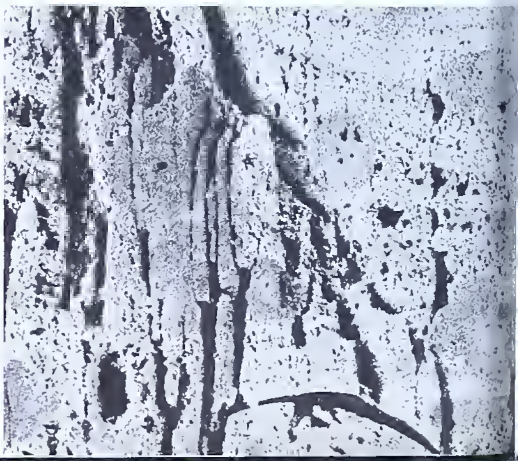


PLATE 10. ACID-ETCHED SURFACES OF CALCARENITES AND CALCILUTITES CONTAINING BURROW-LIKE STRUCTURES.

All 3X magnification. Sections are cut perpendicular to bedding surfaces and are oriented with top of section toward top of plate.

Figure 1. Calcilutite containing numerous silicified dark-colored worm burrows, many of which are dolomitized in the centers. Dark color apparently is from included organic matter which tends to be associated with more siliceous parts. Milesburg Member at Roaring Spring, about 11 feet above base.

Figure 2. Calcilutite containing burrows that are not silicified. New Enterprise Member at Bellefonte, about 14 feet above base.

Figure 3. Calcarenite, cross-laminated, with silicified burrows. Vertical fractures cut worm burrows as well as other parts of rock, indicating that silicification probably occurred before fracturing and hence could not result from weathering. Coleville Member at Bellefonte, about 5 feet above base.

Figure 4. Calcarenite with silicified and partly dolomitized burrows. Milesburg Member at Bellefonte, about 2 feet above base of exposure.

Figure 5. Calcarenite with silicified burrow. Silica apparently moved through and downward from burrow. Milesburg Member at Roaring Spring, about 42 feet below top.

Figure 6. Similar to Figure 5. Milesburg Member at Roaring Spring, about 32 feet above base.

Figure 7. Calcarenite, partly laminated, containing silicified and partly dolomitized burrows. Original position of burrow apparently is marked by white dolomitized circle. Sample also contains silicified crinoid stem plates. Milesburg Member at Roaring Spring, about 56 feet above base.

Figure 8. Similar to Figure 3 only more deeply etched. Milesburg Member at Roaring Spring, about 20 feet above base.

PLATE 11. ACID-ETCHED SECTIONS OF RHYTHMIC DEPOSITS FROM THE COBURN FORMATION.

All 2X magnification. Sections are cut prependicular to bedding surfaces and are oriented with top of section toward top of plate.

Figure 1. Incomplete rhythmic deposit showing calcilutite at base, overlain abruptly and irregularly by bioskeletal calcirudite. Dark splotches in calcilutite are burrow-like structures and diagonal mark is saw cut. White parts standing in relief on bioskeletal calcirudite are quartz replacement of parts of brachiopods and crinoid plates. Milesburg Member at Bellefonte, about 3 feet above base of exposure. Thin section of bioskeletal portion is depicted in Plate 8, Figure 3.

Figure 2. Rhythmic deposit showing faintly laminated, impure calcilutite overlain abruptly and very irregularly by bioskeletal calcirudite which grades upward into calcilutite. Irregular contact possibly is erosional contact that slumped while sediment was still soft and unconsolidated. Darker splotches in calcilutite are composed of amorphous silica which apparently was introduced after deposition of sediment. White, silicified fossil parts stand in relief on bioskeletal calcirudite. Milesburg Member at Roaring Spring, about 75 feet above base. Thin section of bioskeletal portion depicted in Plate 8, Figure 1.

PLATE 11

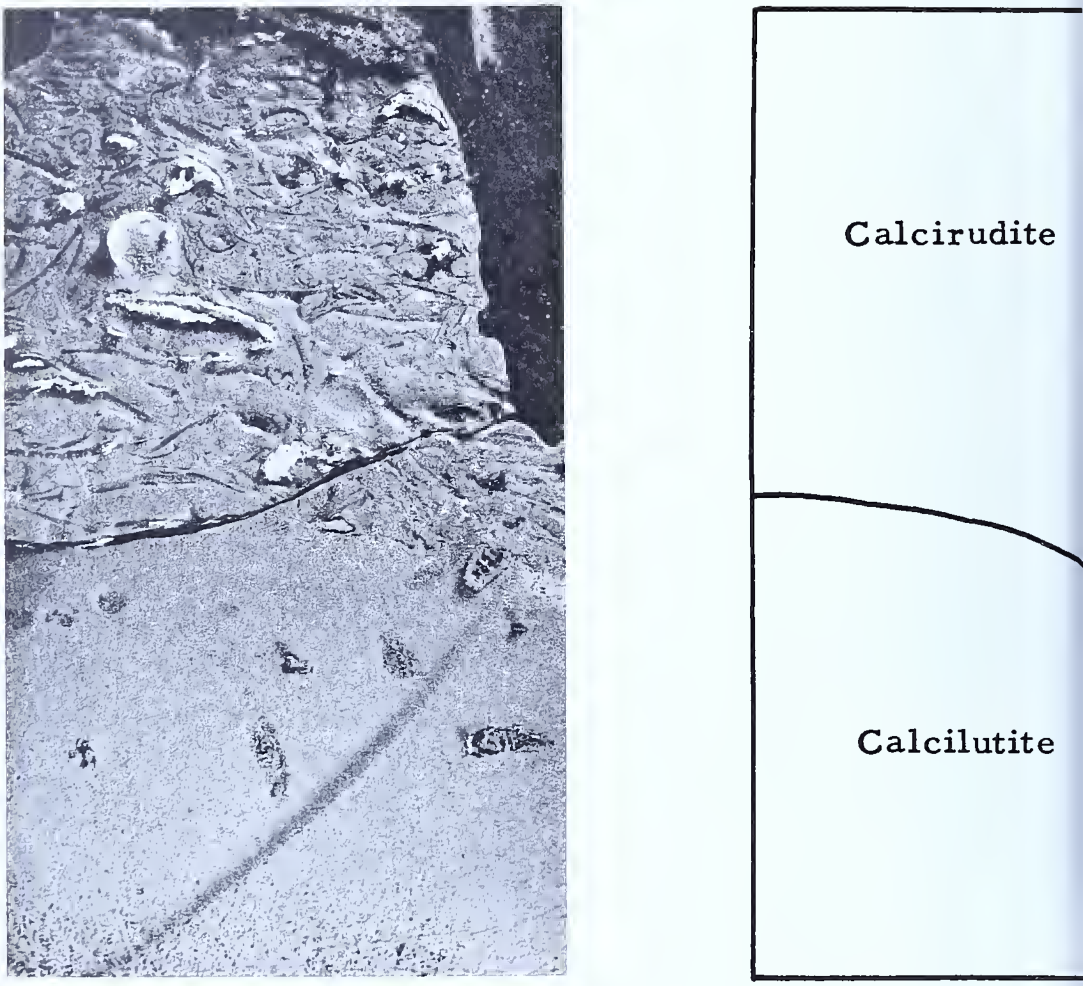


Figure 1

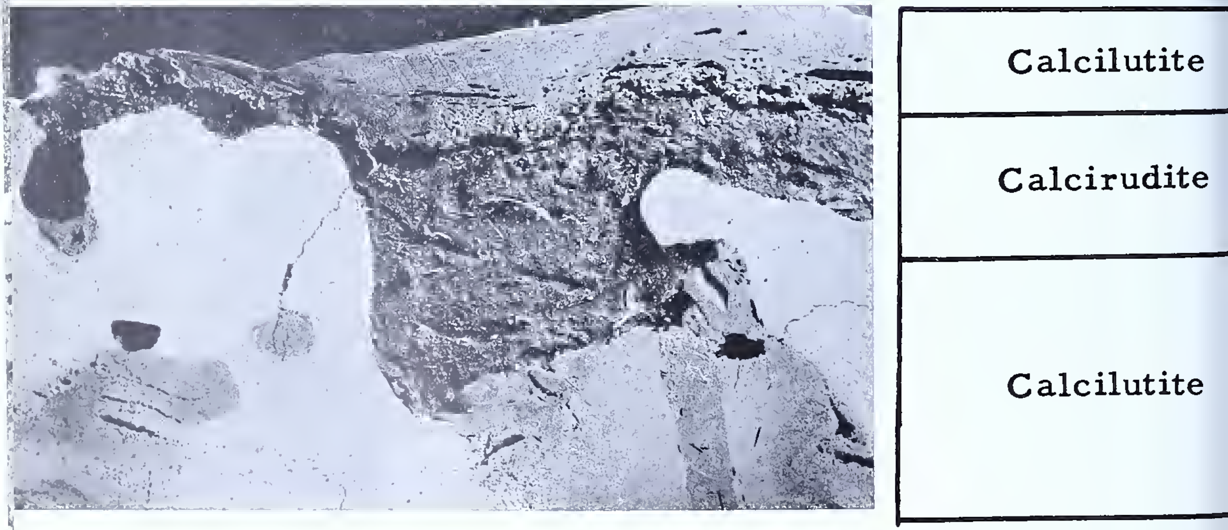
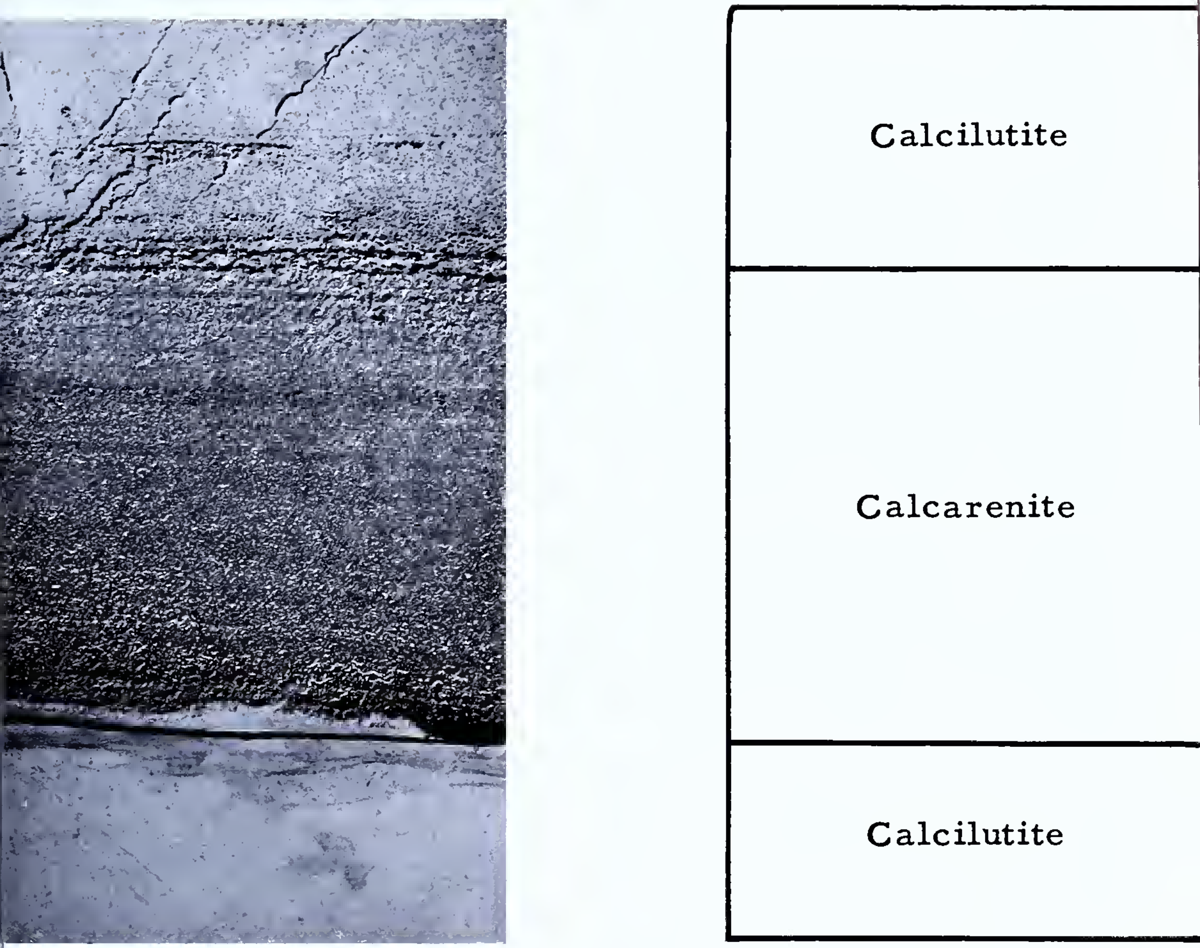


Figure 2

PLATE 12



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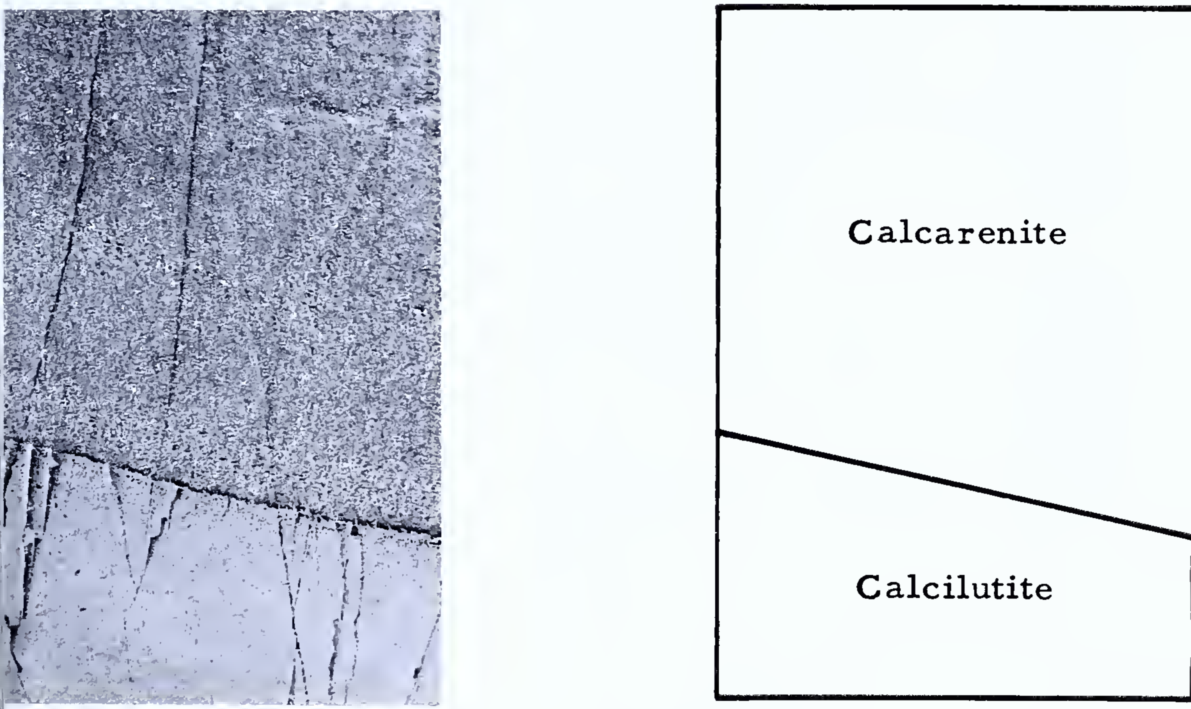

Figure 2

PLATE 12. ACID-ETCHED SECTIONS OF RHYTHMIC DEPOSITS FROM THE ROARING SPRING MEMBER OF THE SALONA FORMATION.

All 2X magnification. Sections are cut perpendicular to bedding surfaces and are oriented with top of section toward top of plate.

Figure 1. Incomplete rhythmic deposit with calcilutite at base, overlain abruptly and irregularly by laminated calcarenite which grades upward into calcilutite. White specks standing in relief on surface of calcarenite are crystals of quartz and feldspar. Calcarenite is much purer than calcilutite. Roaring Spring Member at Roaring Spring, about 22 feet above base. Thin section across abrupt contact is shown in Plate 9, Figure 1.

Figure 2. Similar to Figure 1. Vertical lines are calcite-filled fractures. Roaring Spring Member at Roaring Spring, about 20 feet from top.